

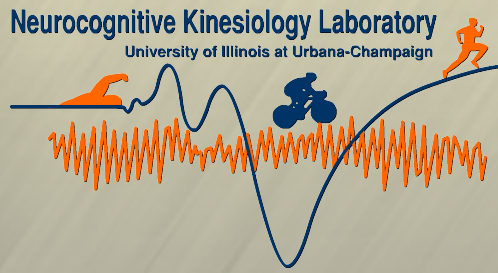
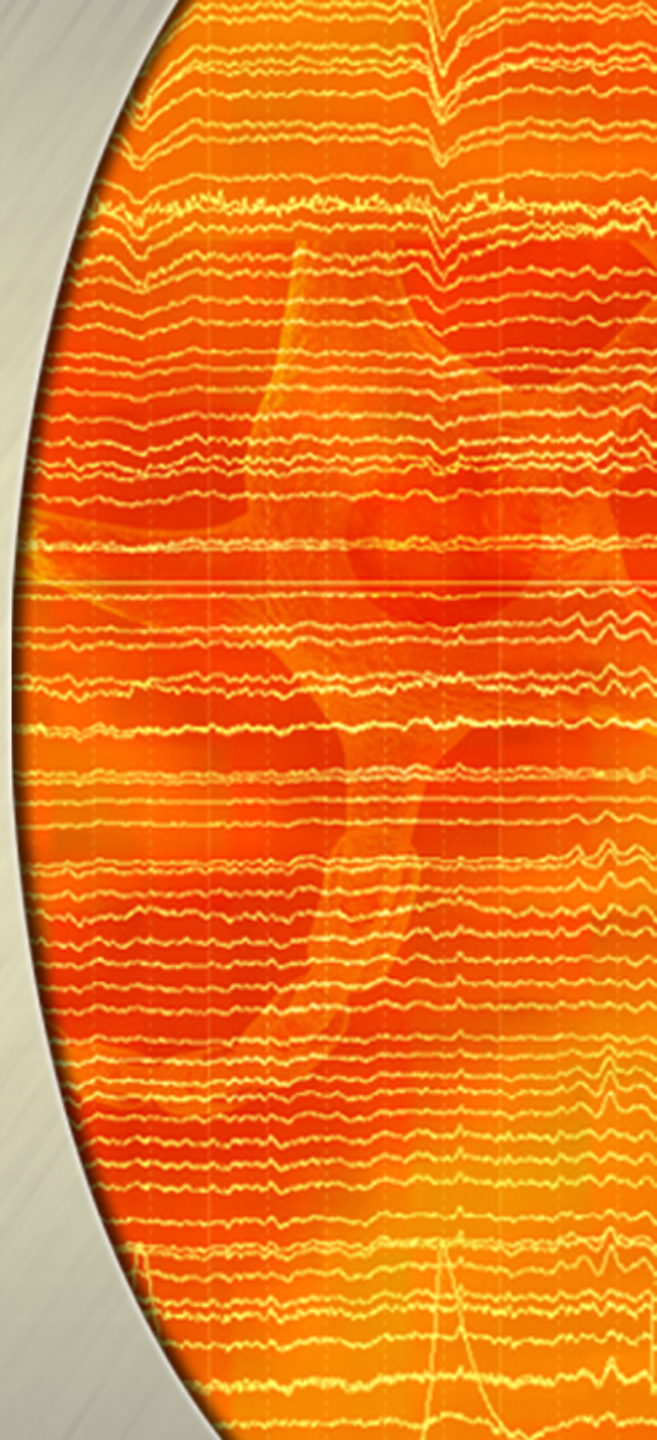
# The Relation of Childhood Fitness to Brain Health, Cognition, and Achievement

Charles H. Hillman, Ph.D.

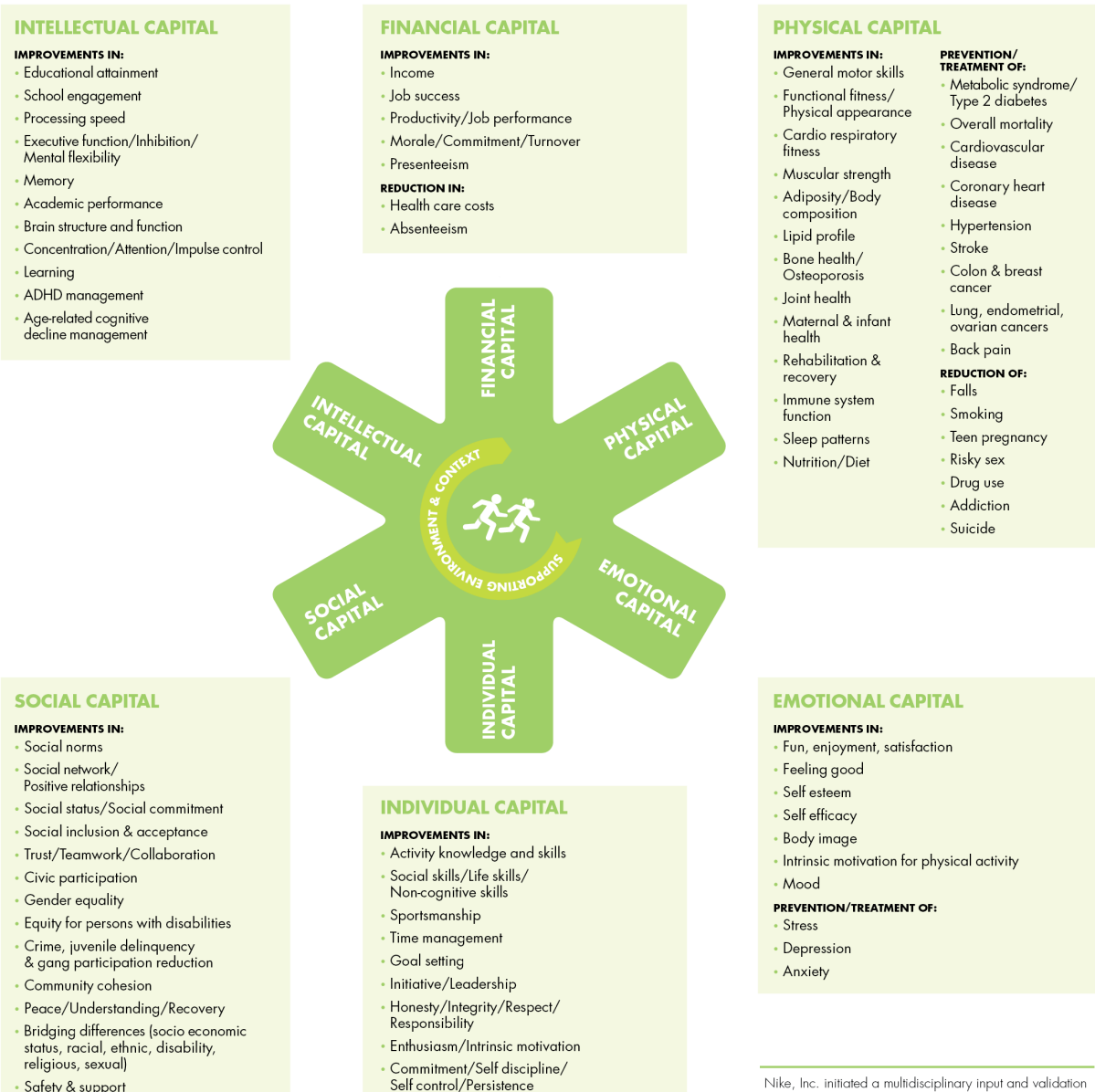
Neurocognitive Kinesiology Laboratory

Department of Kinesiology & Community Health

University of Illinois at Urbana-Champaign



# THE HOLISTIC BENEFITS OF PHYSICAL ACTIVITY ARE NOT FULLY RECOGNIZED



Nike, Inc. initiated a multidisciplinary input and validation

Children are becoming increasingly sedentary.



# Increased prevalence of being **overweight** and **unfit.**



# Military Preparedness



- The U.S. Department of Defense estimates that as many as 1/3 of military-age youth are ineligible for service due to weight
- Nearly 27% of 17-24 year olds are too overweight to serve
- \$1 billion spent on management of overweight & obesity in recruits

Sedentary Childhood  
often leads to  
Sedentary Adulthood.



Recent estimates have indicated that younger generations will live

**less healthy**

and have

**shorter lives**

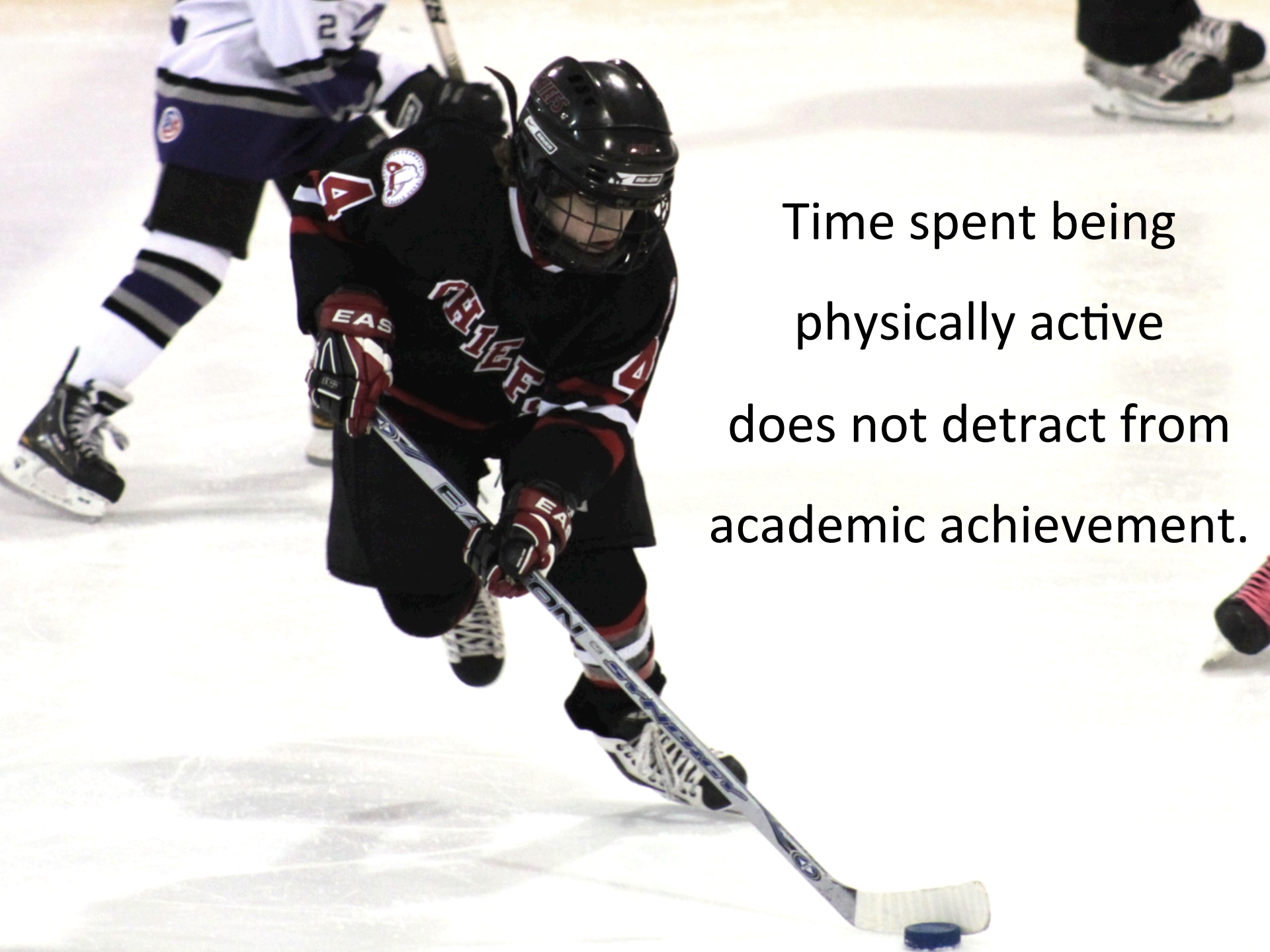
than their parents.



A growing number of schools are **eliminating daily physical activity** opportunities to provide additional classroom time on formal academic topics.

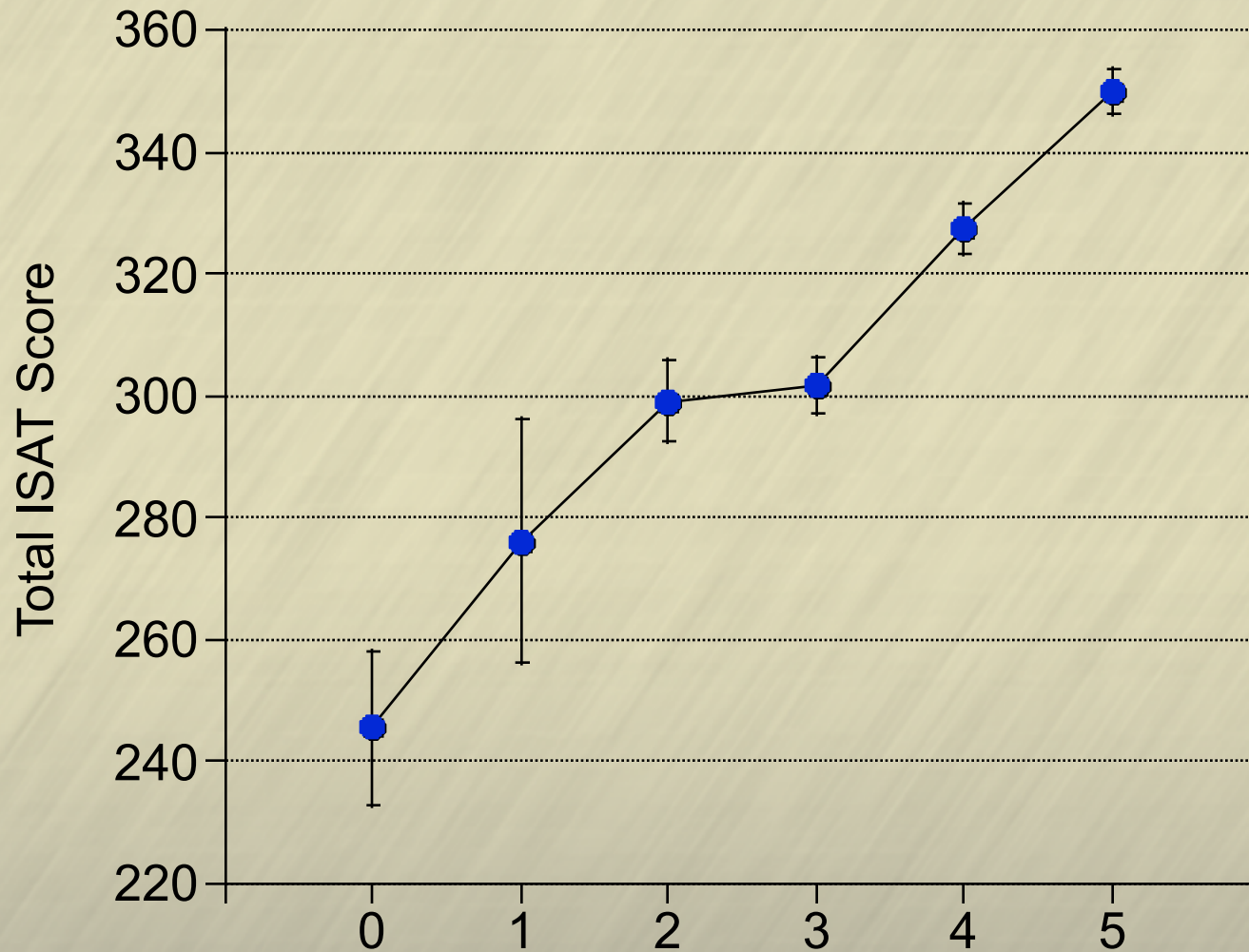
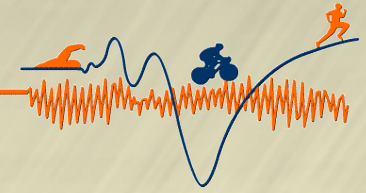




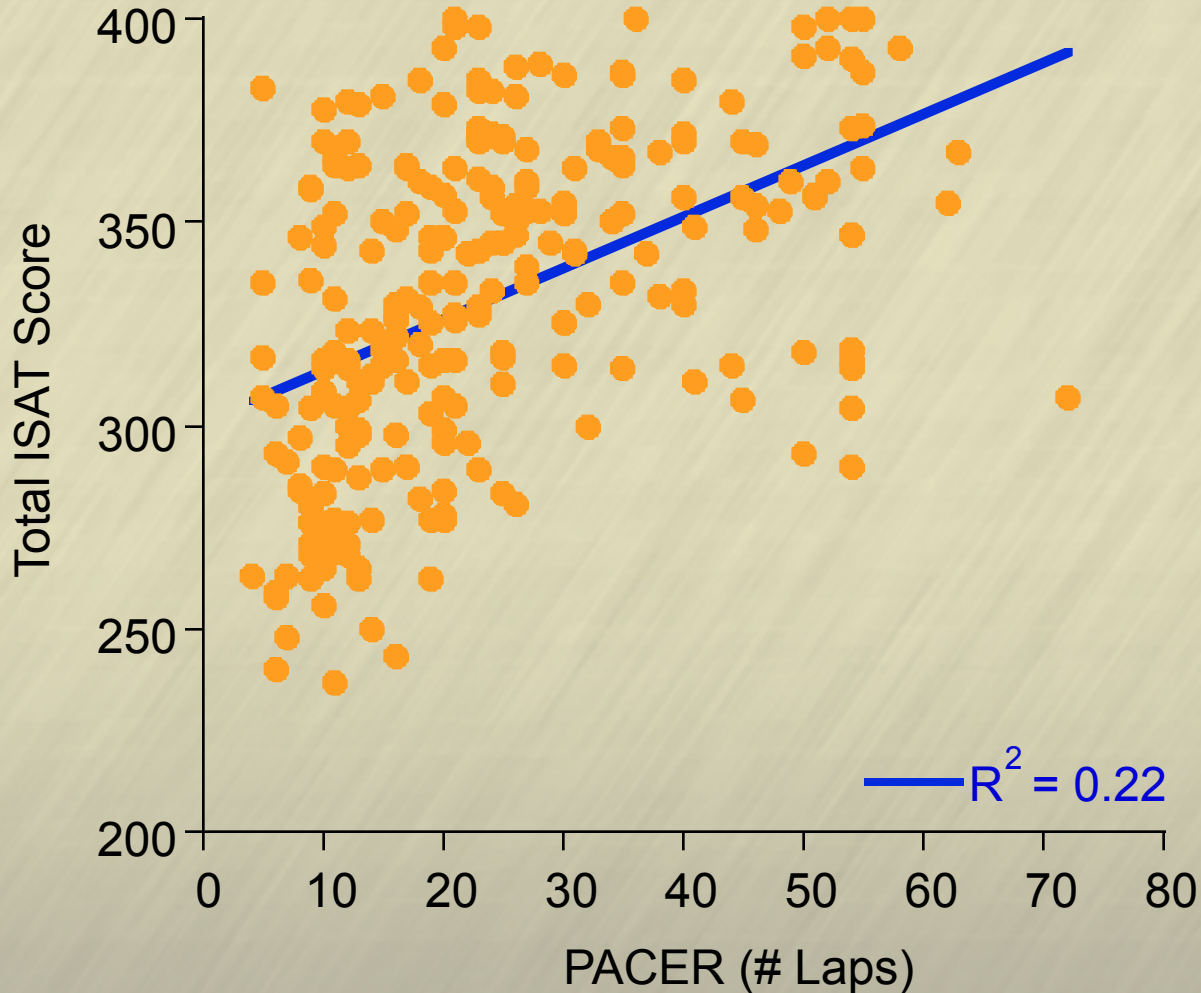
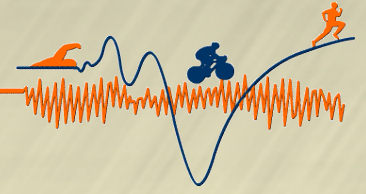


Time spent being  
physically active  
does not detract from  
academic achievement.

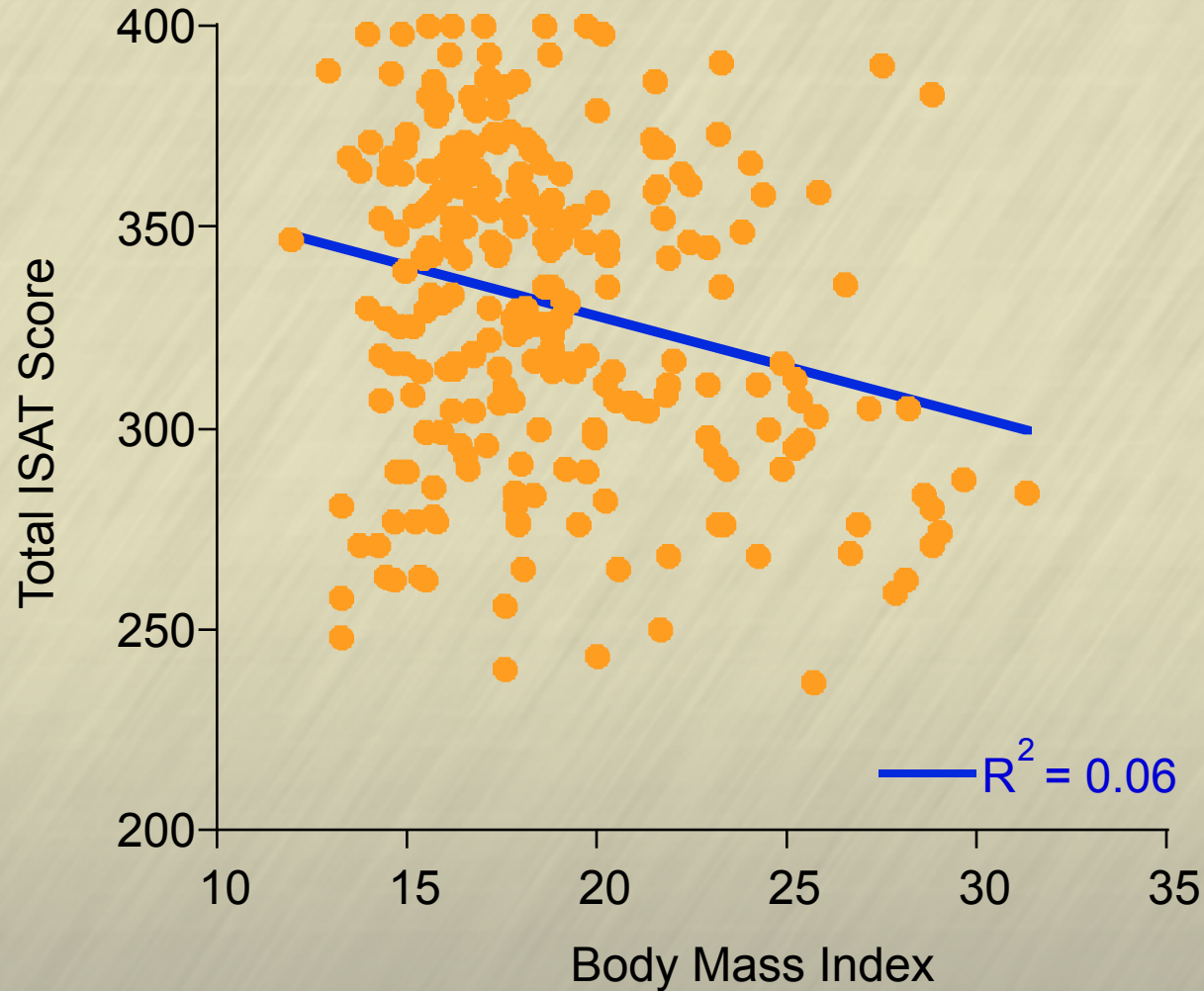
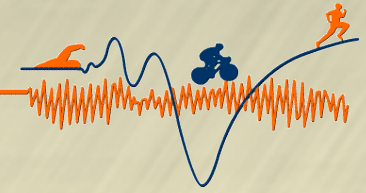
# Physical Fitness & Achievement Test Performance



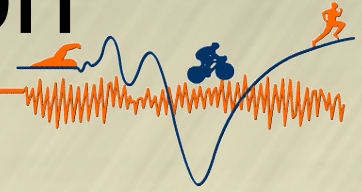
# Aerobic Fitness & Achievement Test Performance



# Body Mass Index & Achievement Test Performance

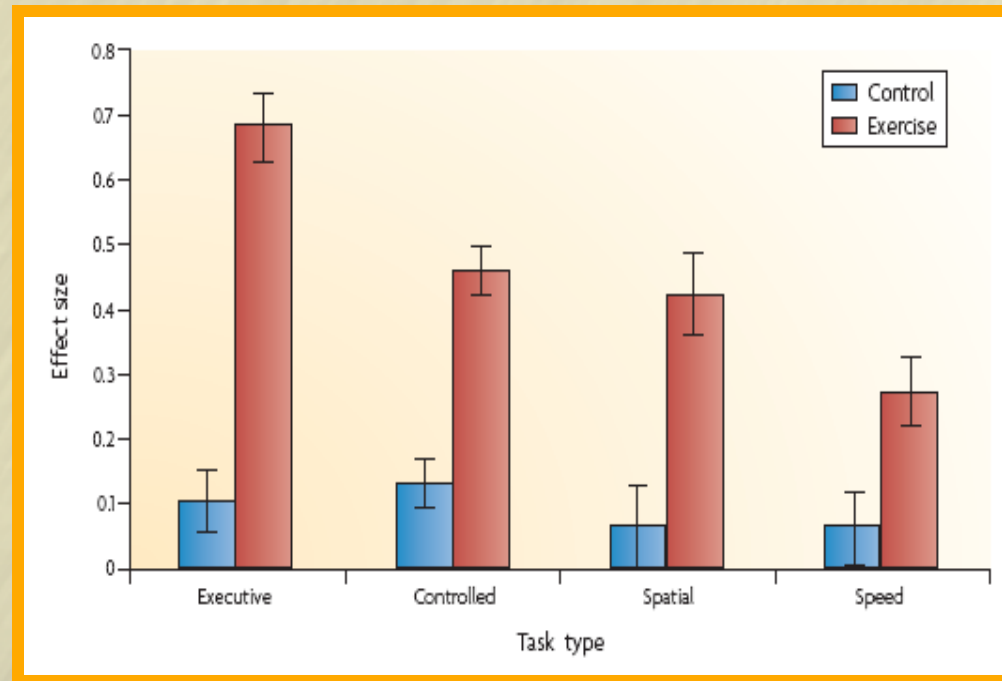


# PA Effects on Cognition



- Meta-analyses have determined that PA is positively associated with cognition.

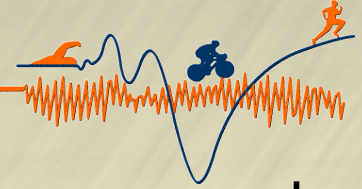
- Ettnier et al. (1997) found an  $ES = .25$  SD for perceptual, cognitive, & motor tasks.
- Colcombe & Kramer (2003) observed that this relationship was greater for tasks requiring extensive executive control ( $ES = .5$  SD).



- Recent meta-analyses (Lambourne & Tomporowski, 2010; Smith et al., 2010) corroborate this beneficial relationship.

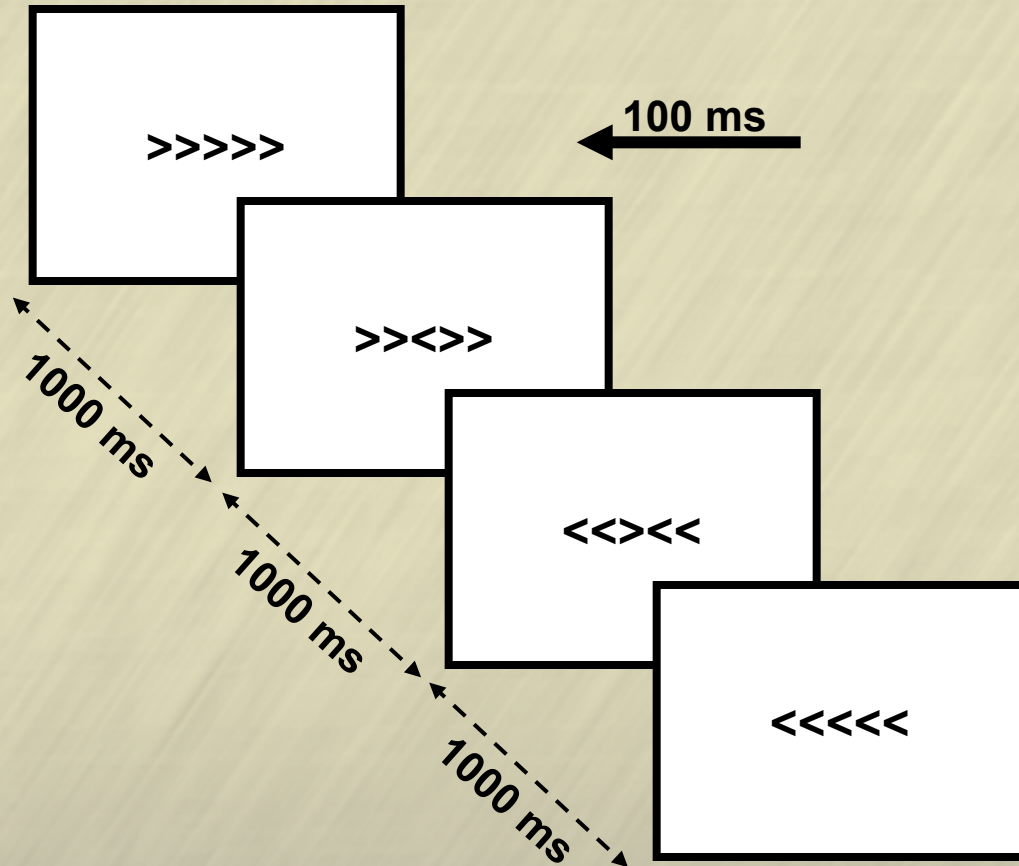
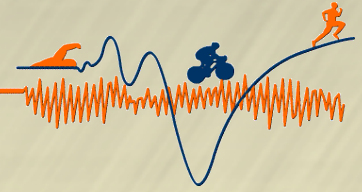
# Executive Control

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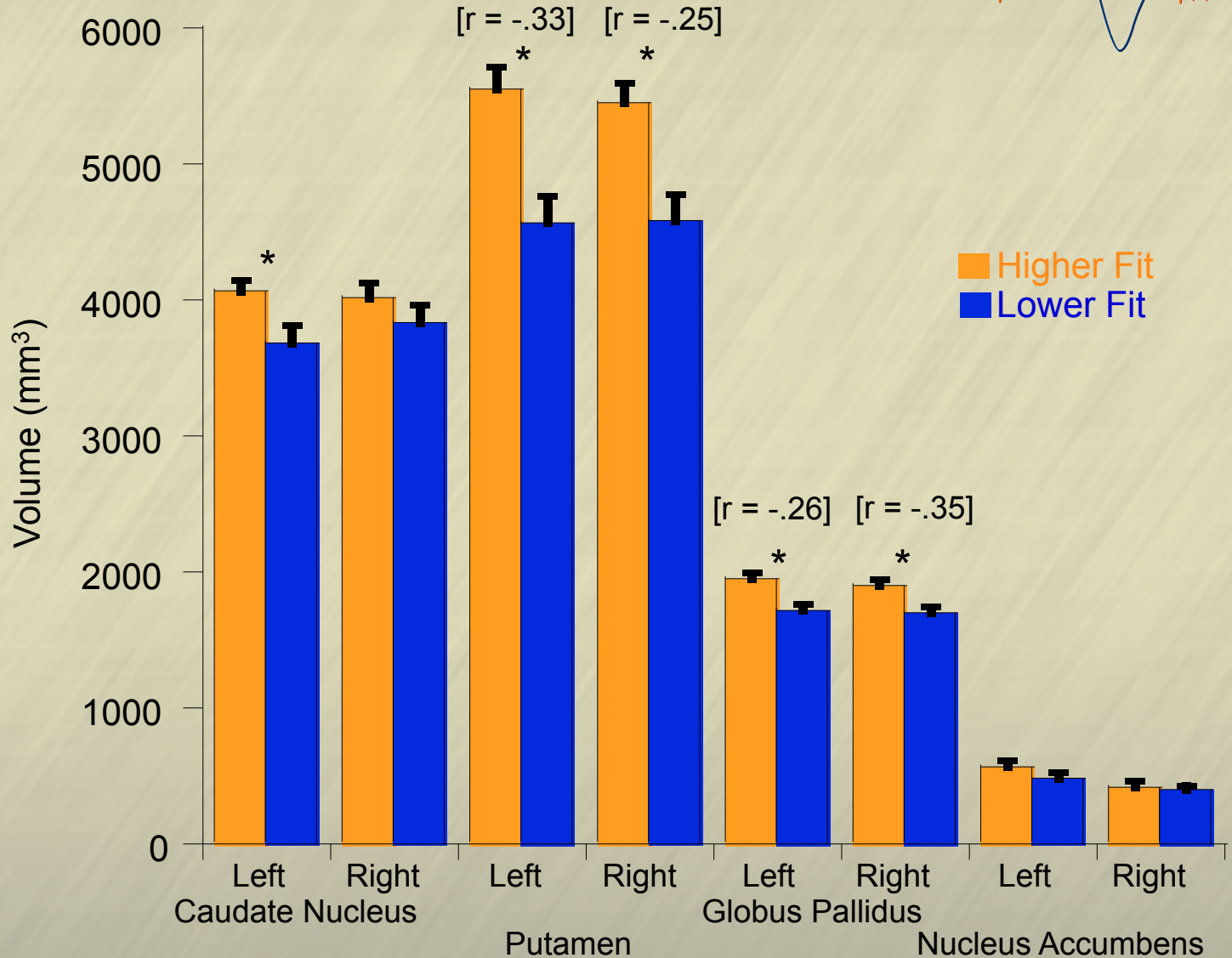
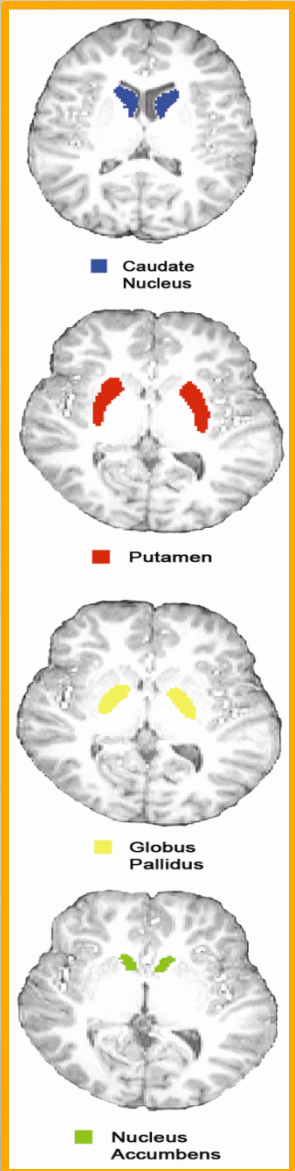
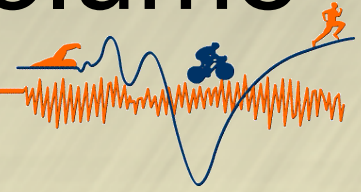


- Executive control is required to meet desired outcomes and intended goals.
- Situations in which executive control is required include:
  - Novel tasks, planning, problem solving, conscious choices among alternatives, overriding a strong internal or external pull, etc.
- Core cognitive abilities that constitute what collectively is known as executive function include (Diamond, 2006):
  - Inhibition – the ability to ignore distraction & stay focused
  - Working memory – the ability to hold information in mind and manipulate it
  - Cognitive flexibility – the ability to switch perspectives, focus of attention, or response mappings

# Flanker Task

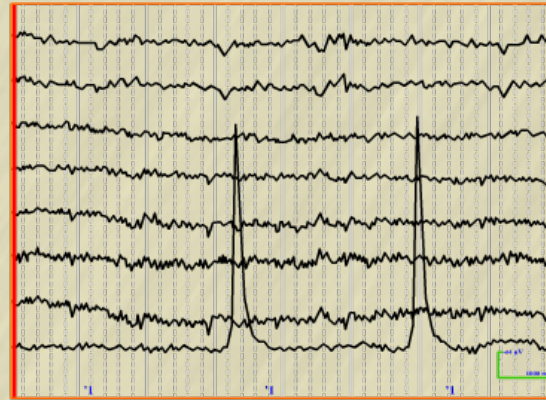
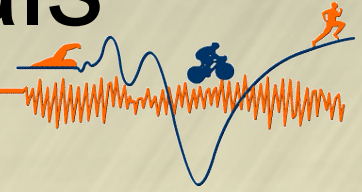


# Fitness & Basal Ganglia Volume

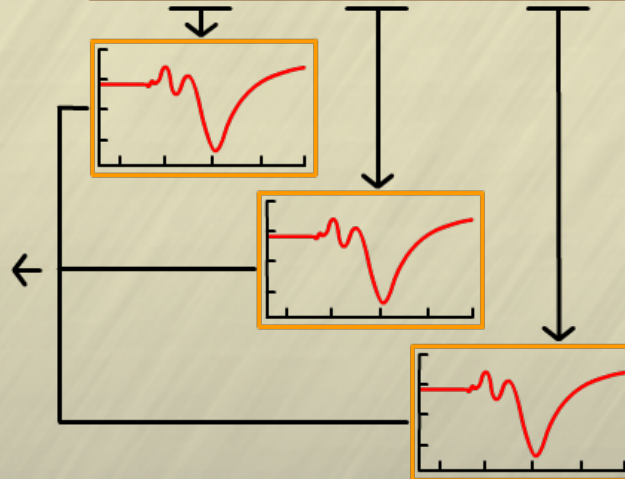
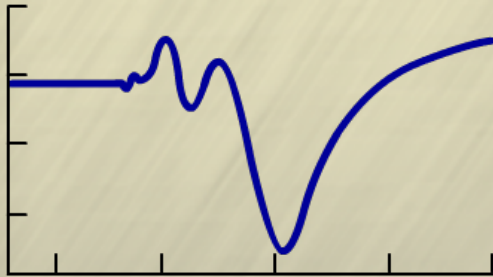




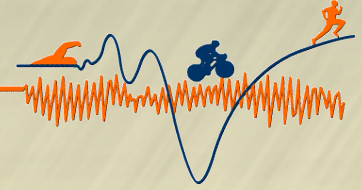
# Event-Related Potentials



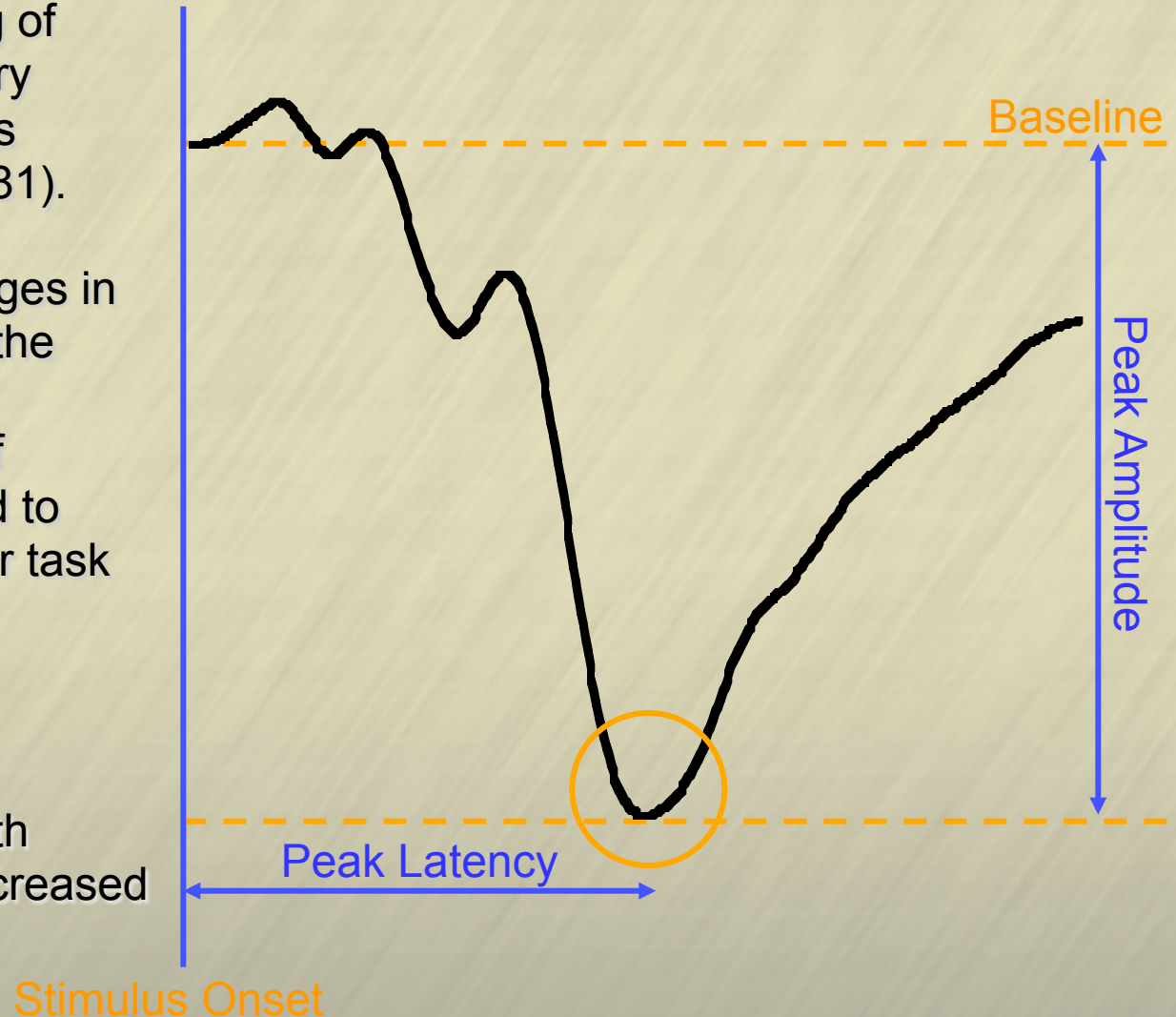
**Trials Averaged Together**



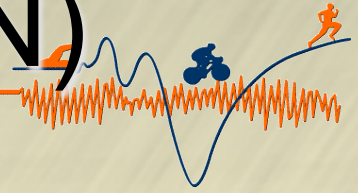
# The P3 Component



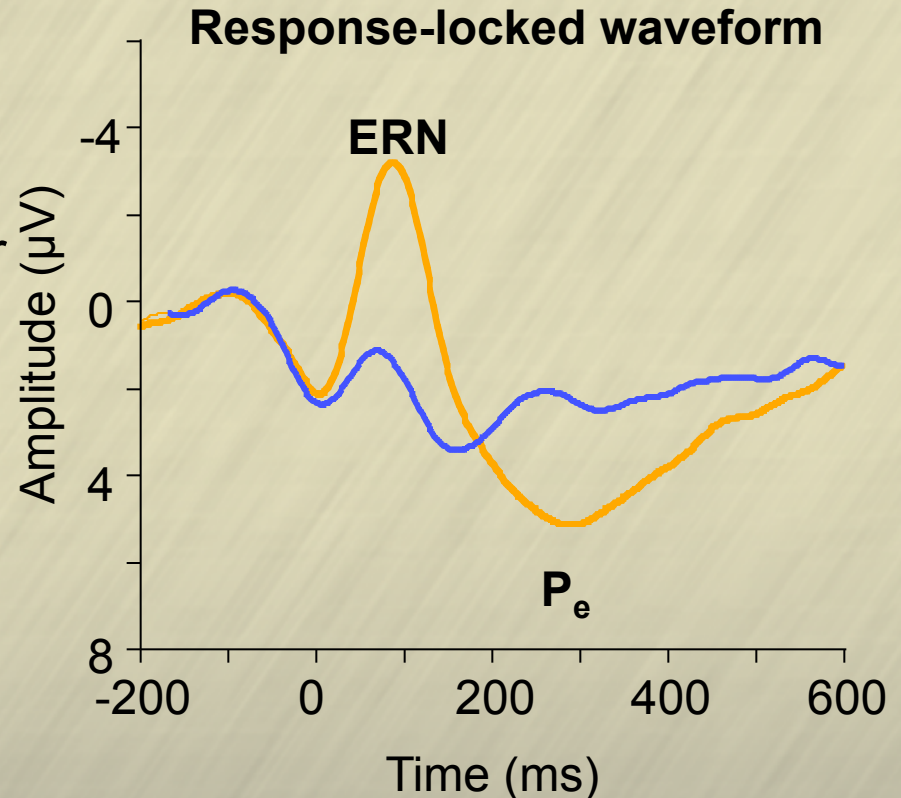
- P3 represents the updating of attention and working memory once sensory information has been analyzed (Donchin, 1981).
- P3 amplitude reflects changes in the neural representation of the stimulus environment and is proportional to the amount of attentional resources needed to engage in a given stimulus or task (Polich & Heine, 1996).
- P3 latency is a measure of stimulus classification speed (Duncan-Johnson, 1981), with longer latencies reflecting increased processing time.



# Action Monitoring (ERN)

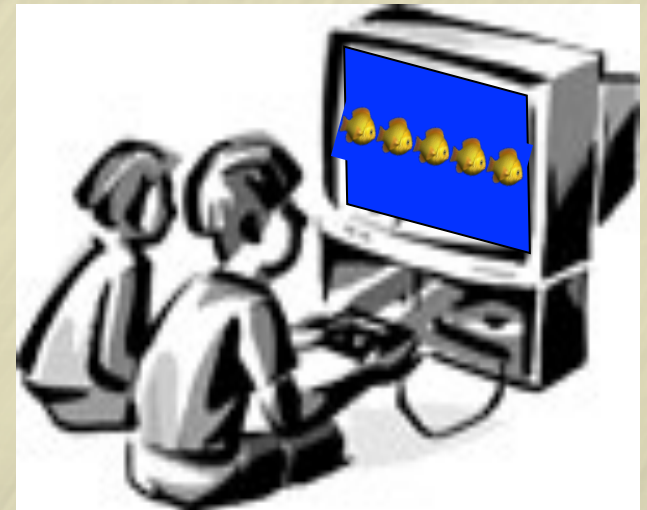
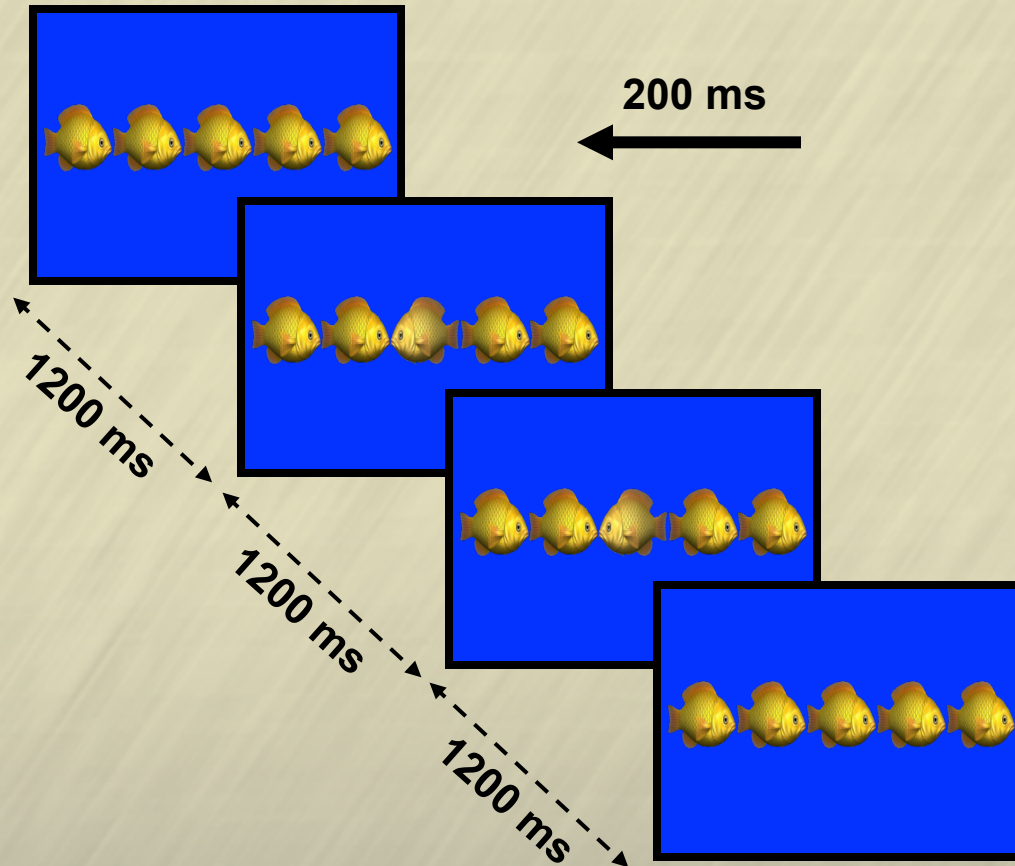
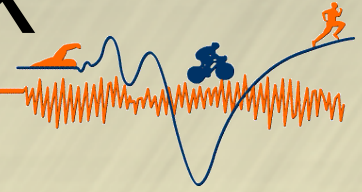


- Error-related negativity (ERN) reflects neuroelectric indices of action monitoring.
- A large negative component of response-locked ERP.
- Generated by the anterior posterior medial frontal cortex.
- The ERN reflects a cognitive learning mechanism used to correct an individual's incorrect responses during subsequent environmental interaction.

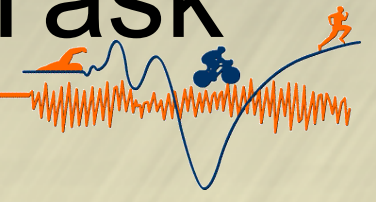


**Fitness**

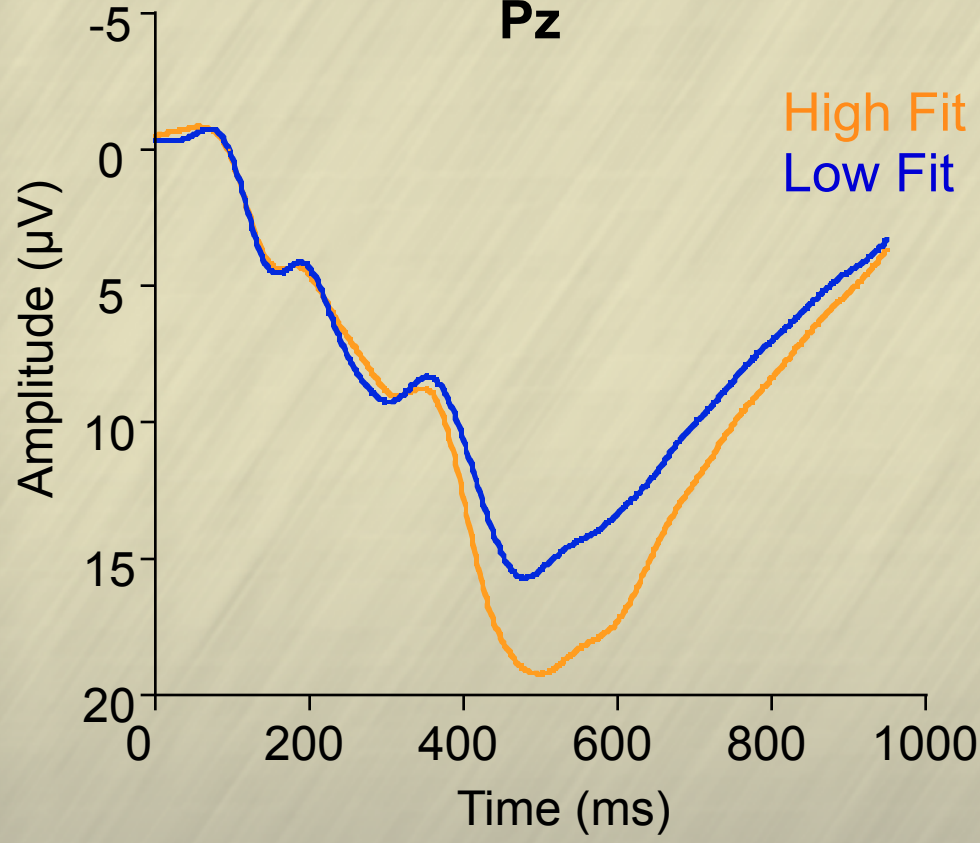
# Modified Flanker Task



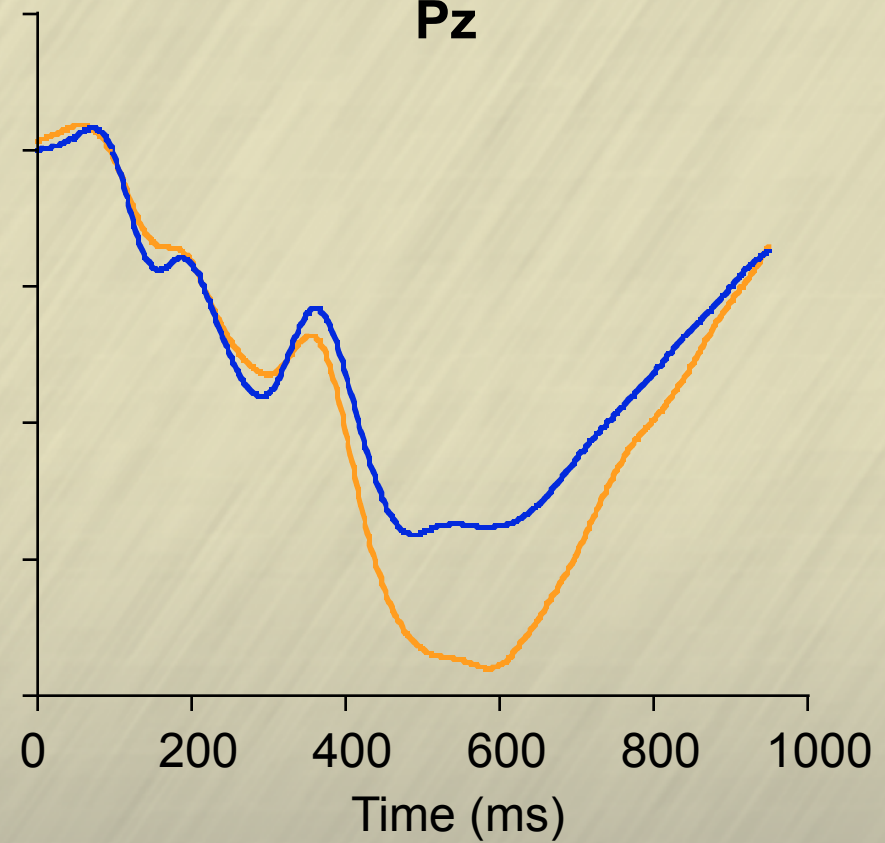
# P3 Amplitude & Flanker Task



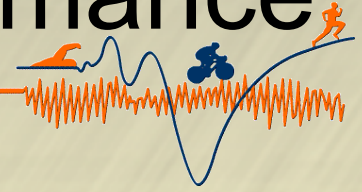
**Congruent  
Pz**



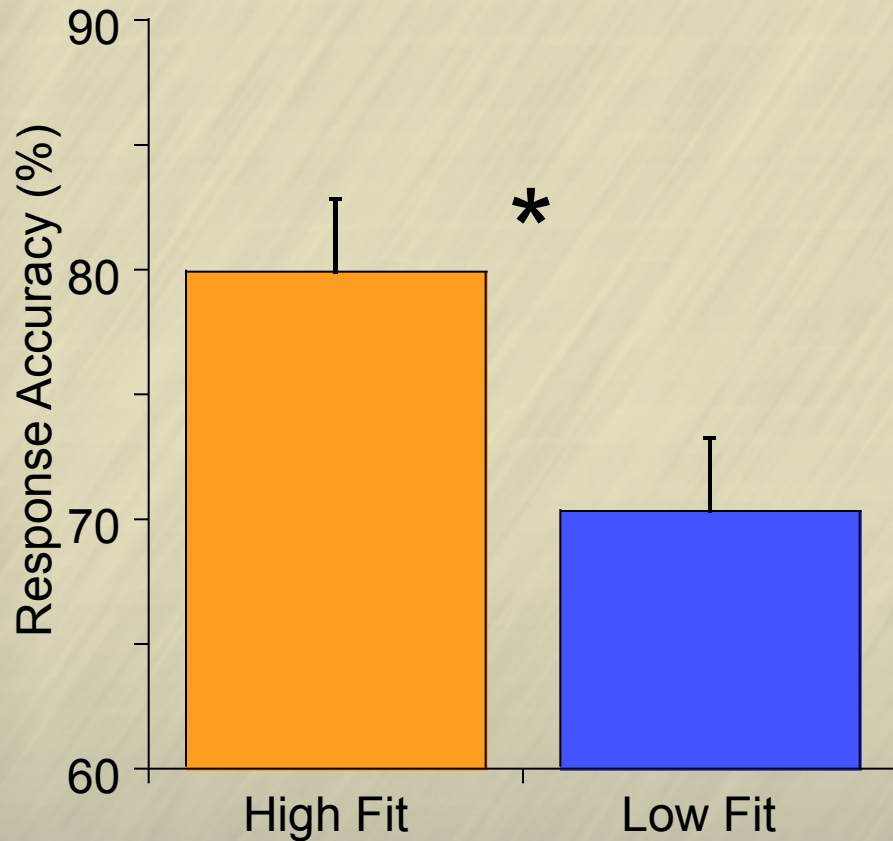
**Incongruent  
Pz**



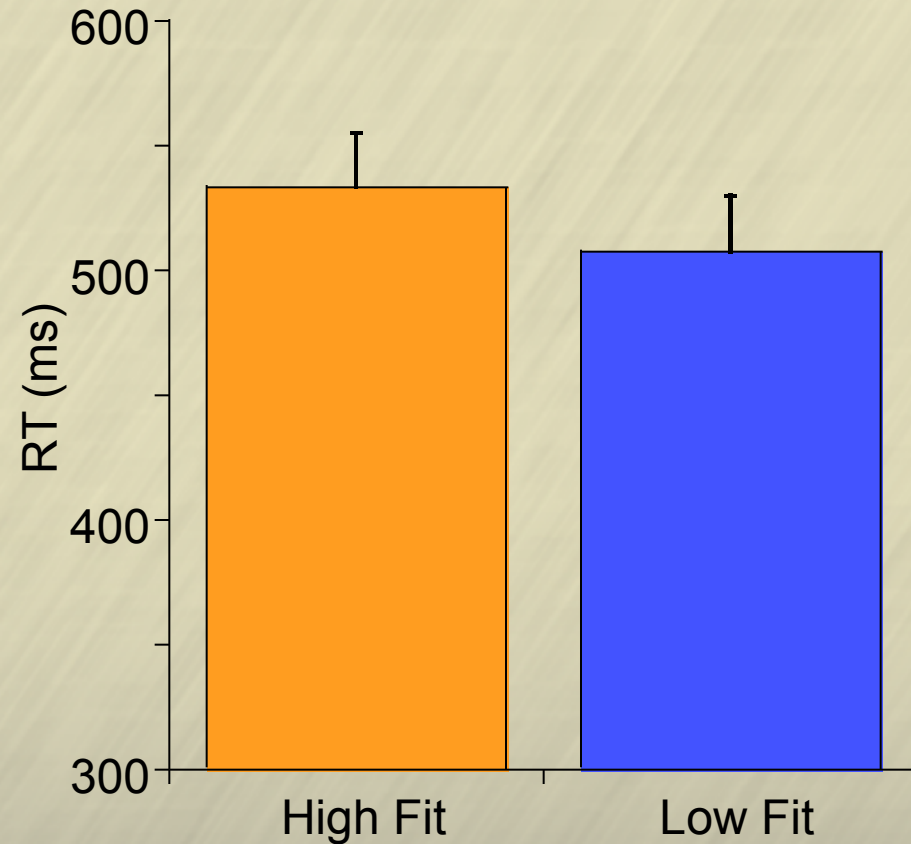
# Fitness & Flanker Task Performance



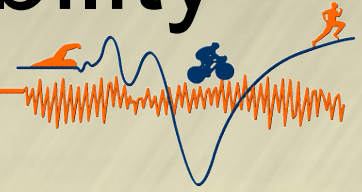
## Task Performance



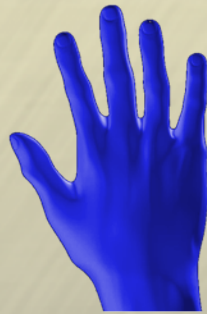
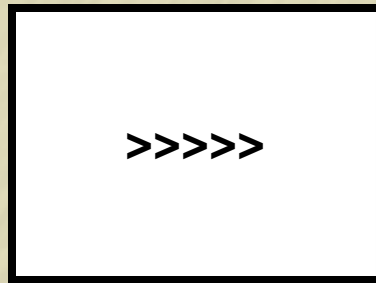
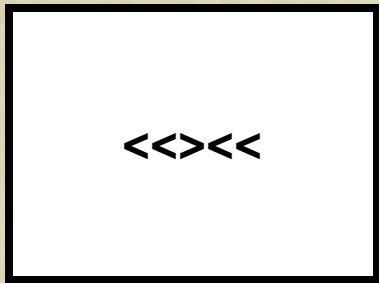
## Reaction Time



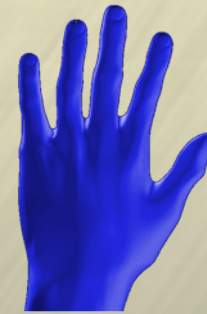
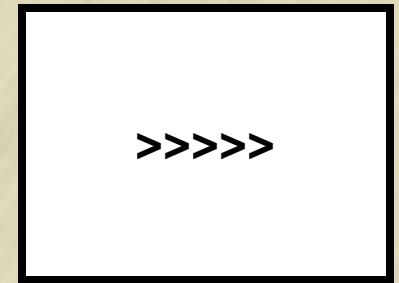
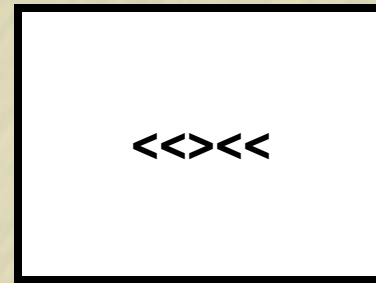
# Fitness & Cognitive Flexibility



Compatible S-R Mapping

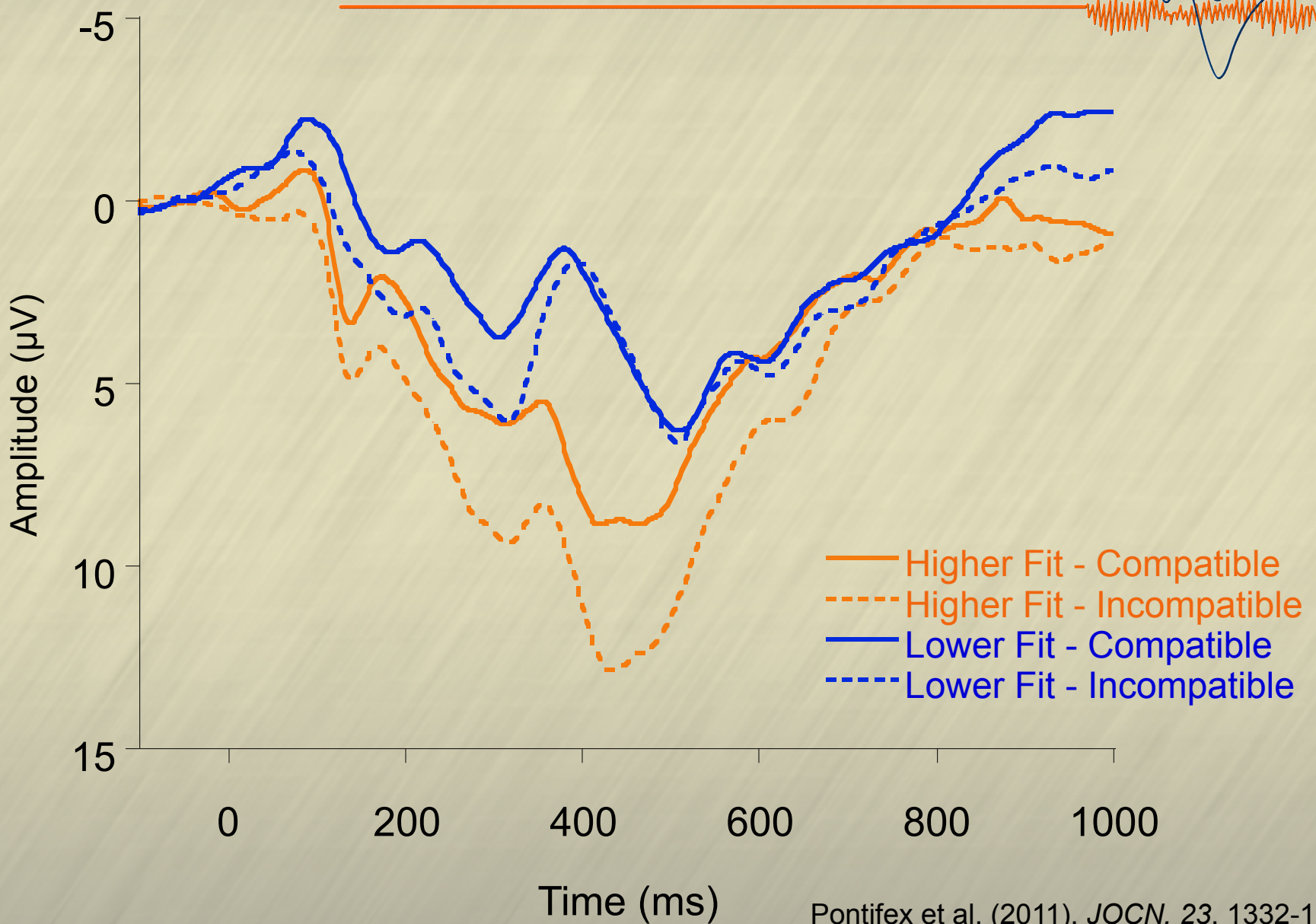
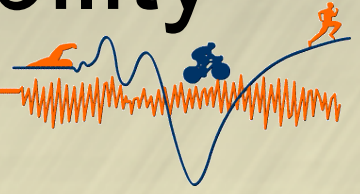


Incompatible S-R Mapping

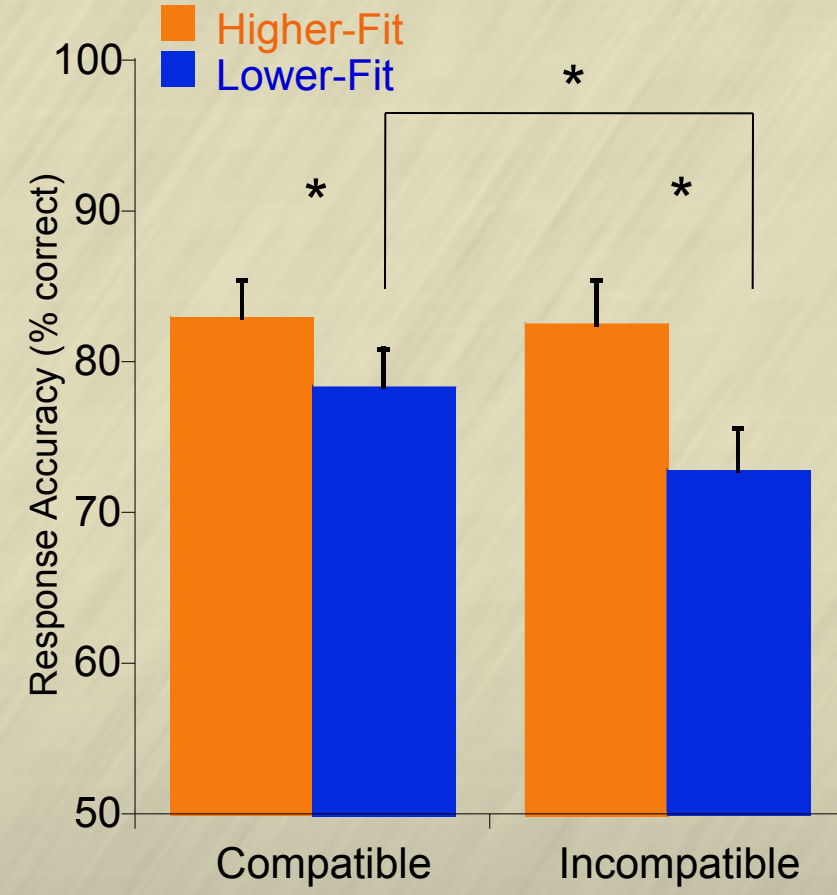
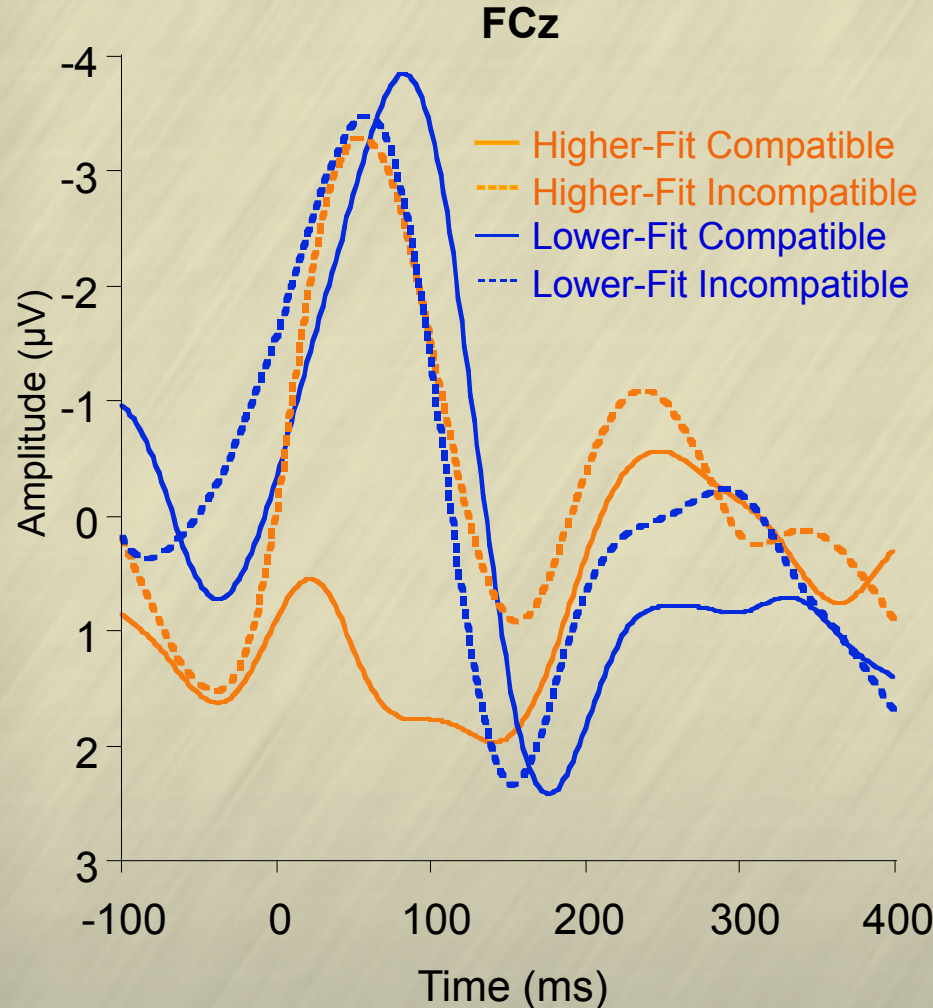
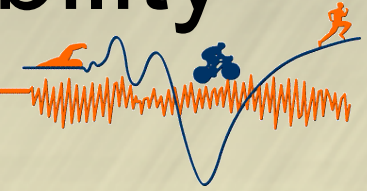




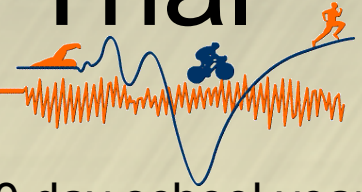
# Fitness & Cognitive Flexibility



# Fitness & Cognitive Flexibility

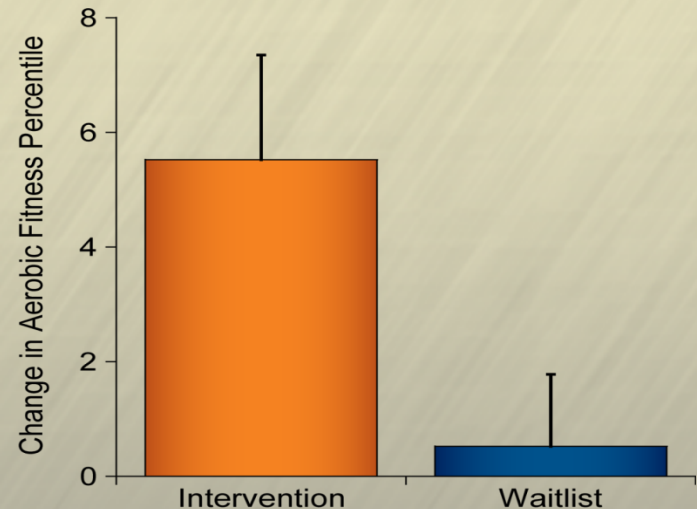
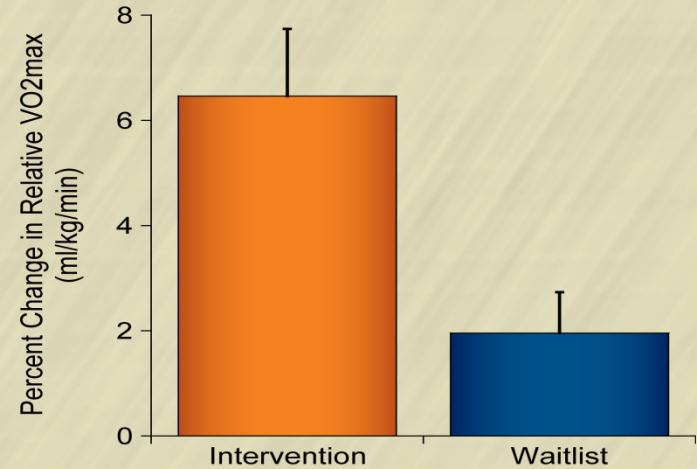


# The FITKids Randomized Trial

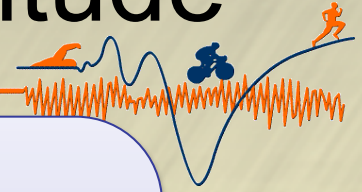


An after-school physical activity program occurring on 150 of the 170 day school year.

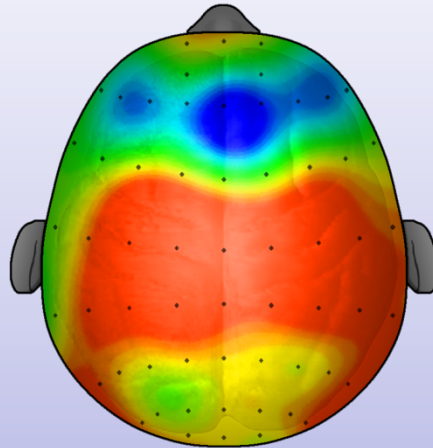
221 Children (Rx = 109, Control = 112) participated in >70 minutes of intermittent moderate to vigorous physical activity following each school day.



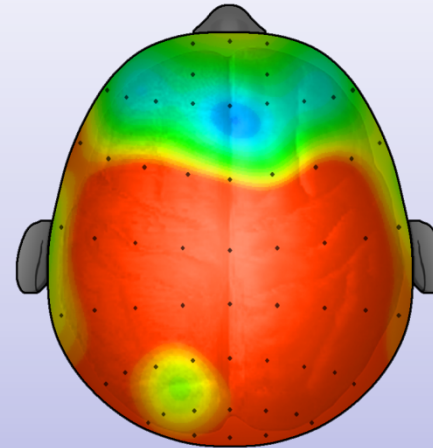
# Change in Flanker P3 Amplitude



**FITKids**  
Intervention

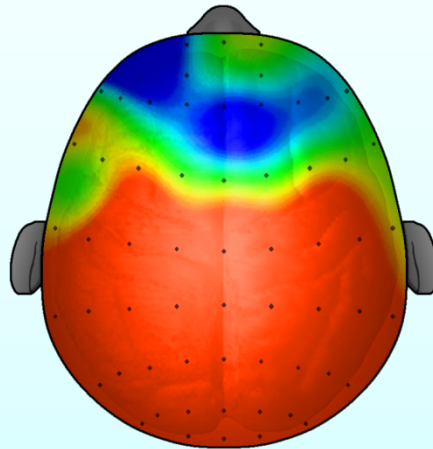


Pretest

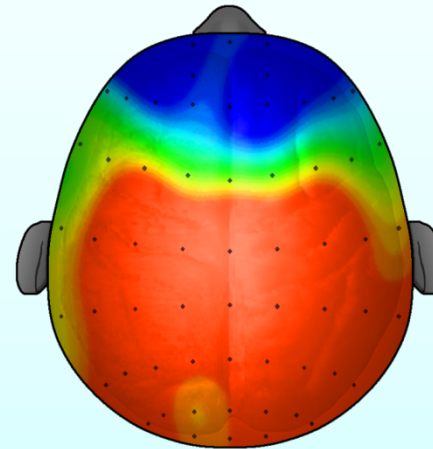


Posttest

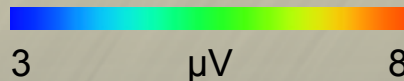
**Waitlist**  
Control



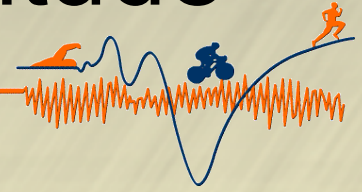
Pretest



Posttest

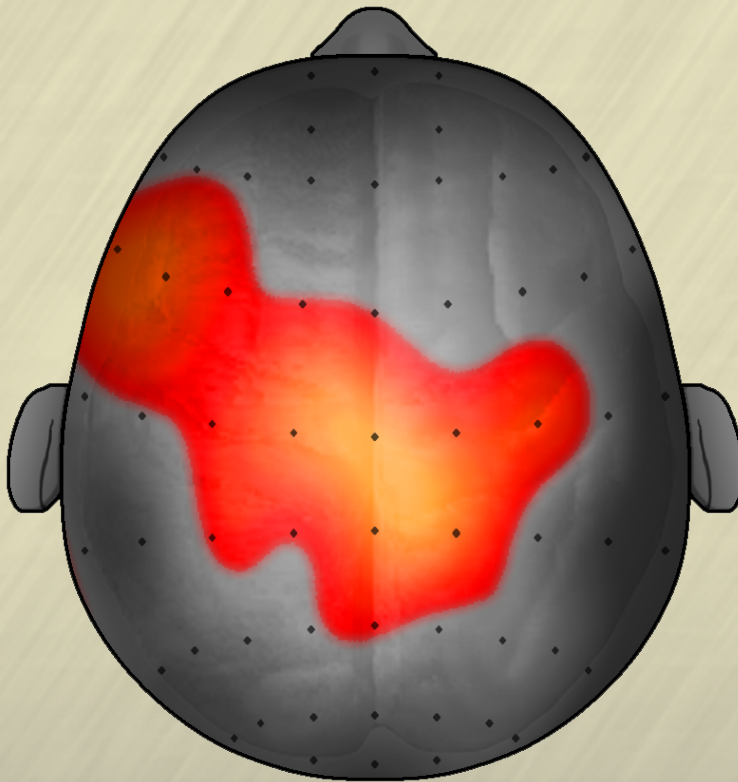


# Change in Flanker P3 Amplitude



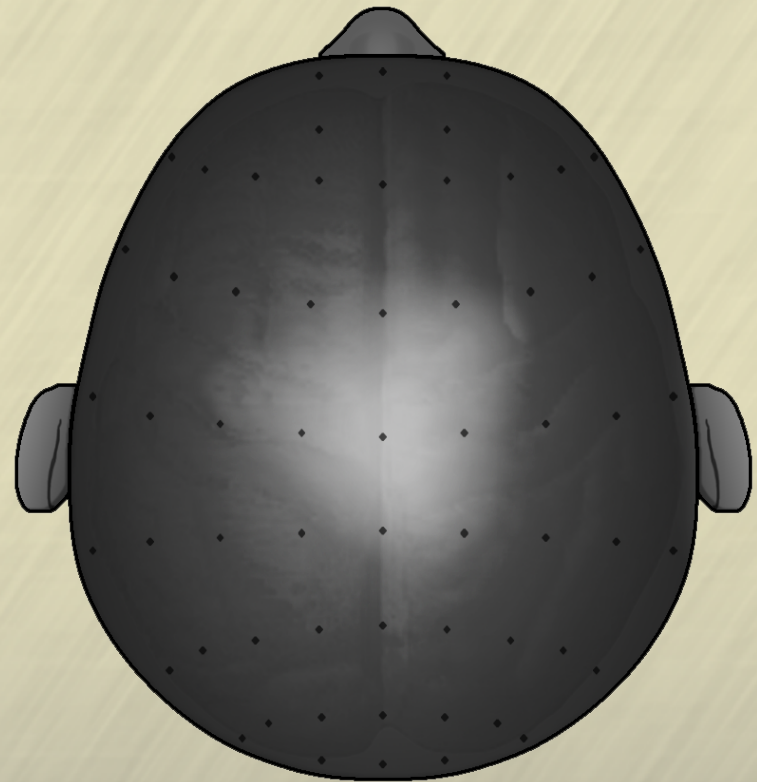
## FITKids

Intervention



## Waitlist

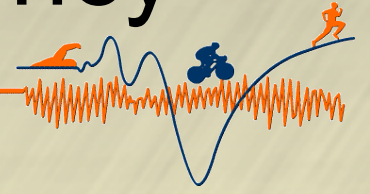
Control



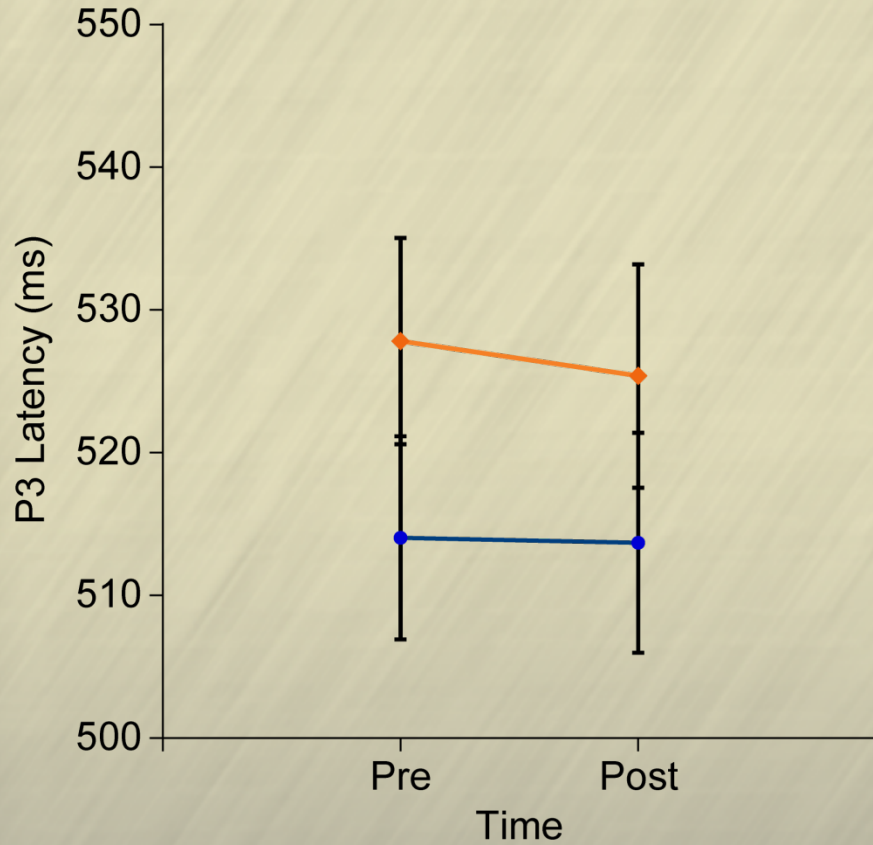
2  $\mu$ V  
 $p = 0.05$

3  $\mu$ V  
 $p < 0.01$

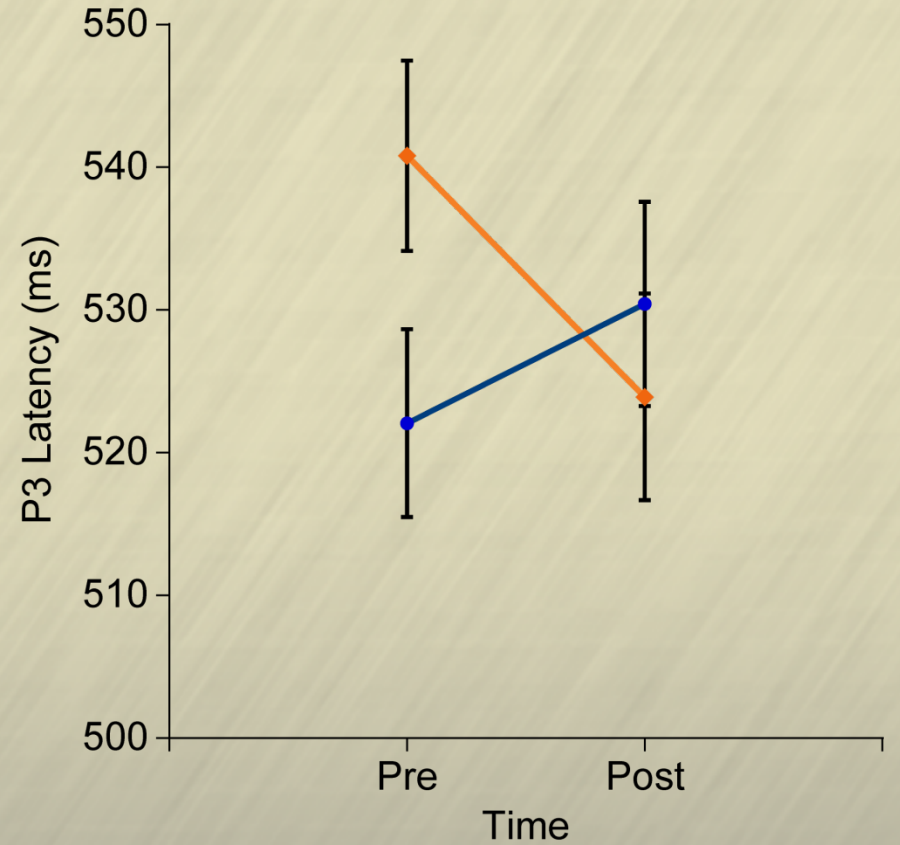
# Change in Flanker P3 Latency



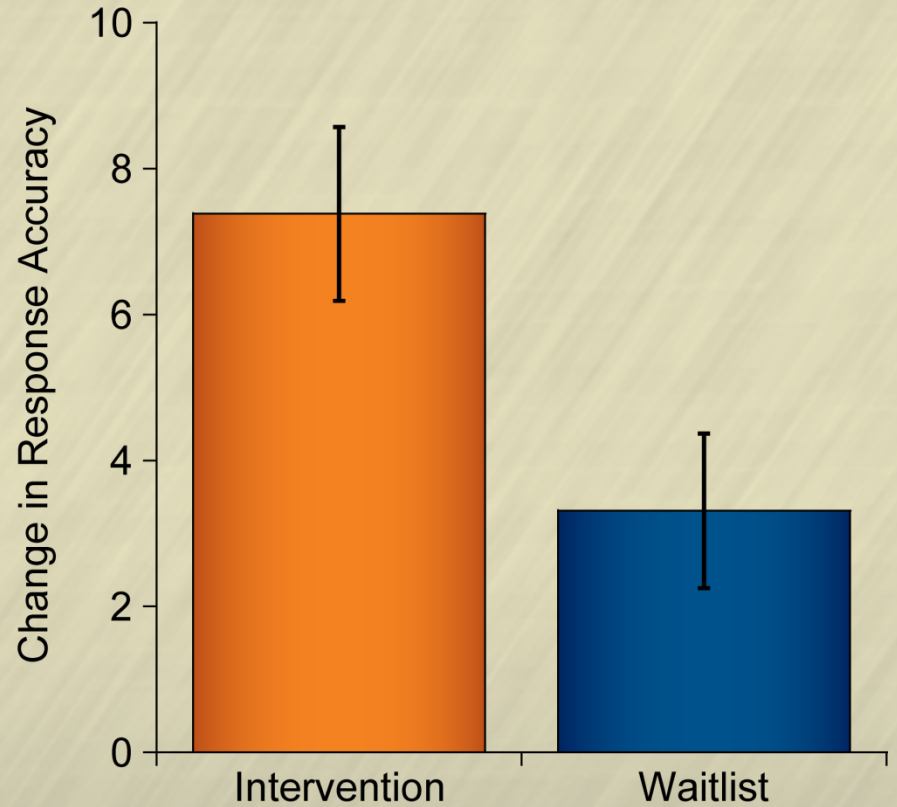
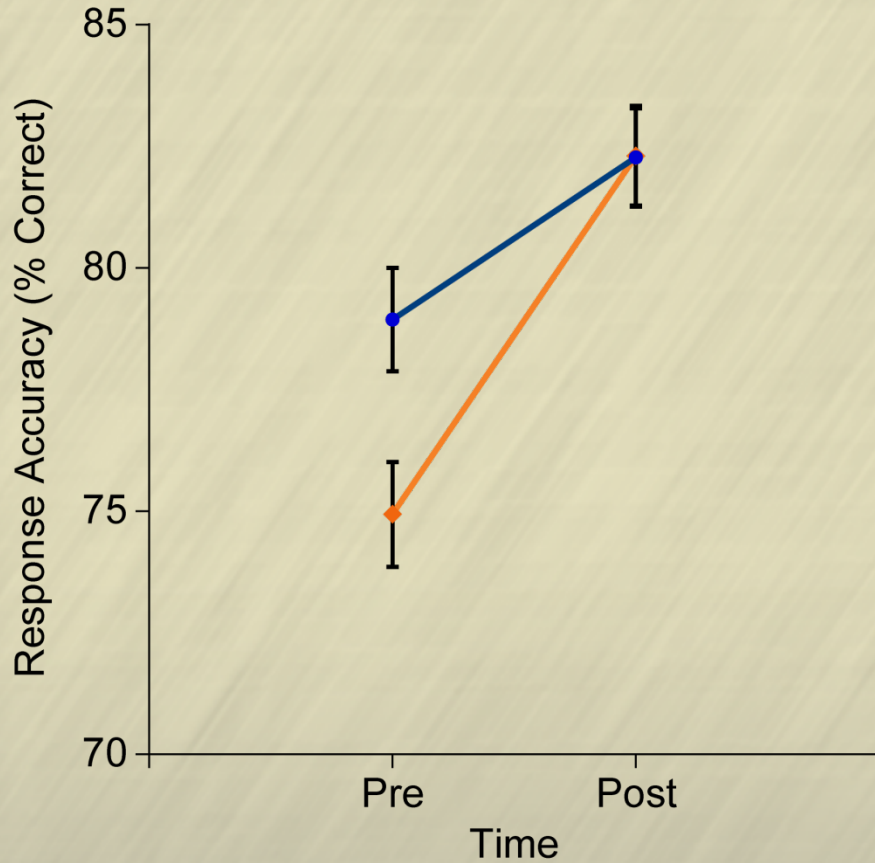
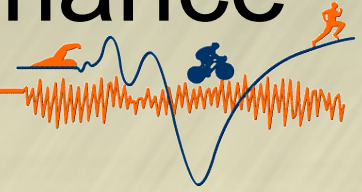
## Congruent



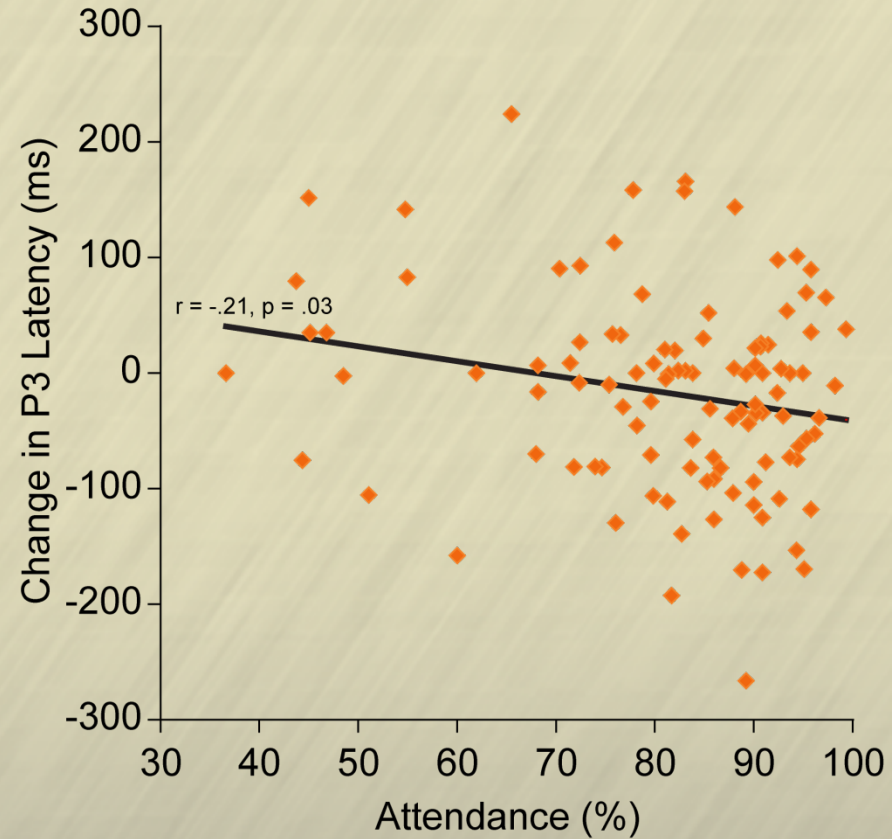
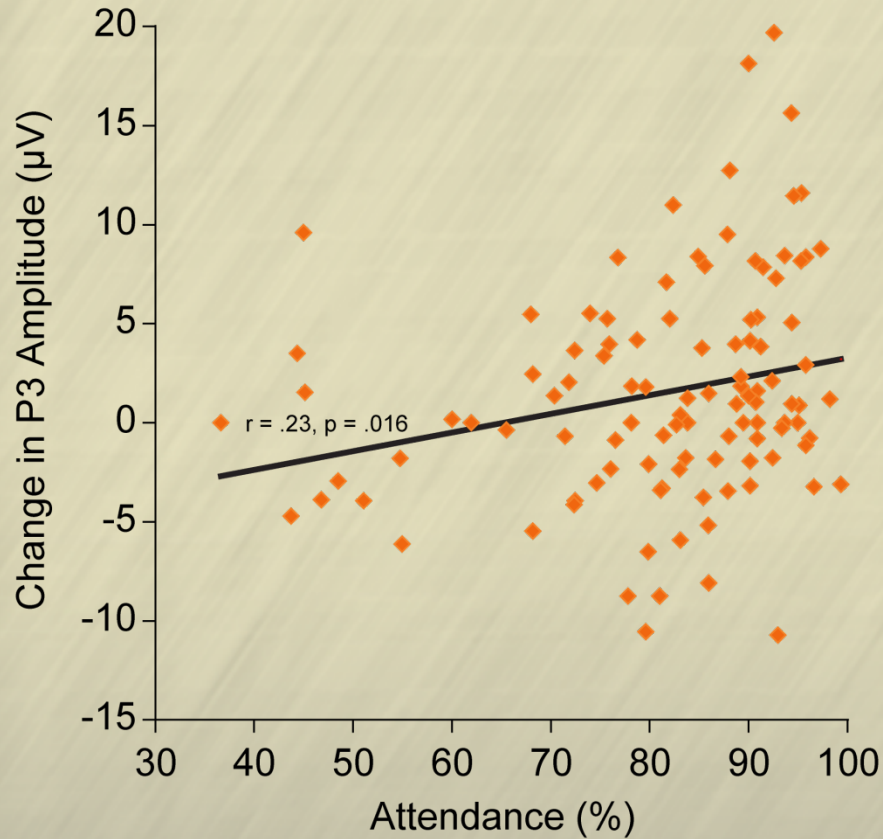
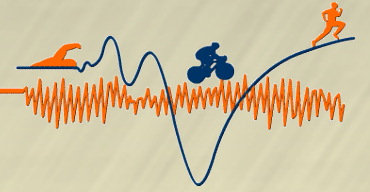
## Incongruent



# Change Flanker Task Performance

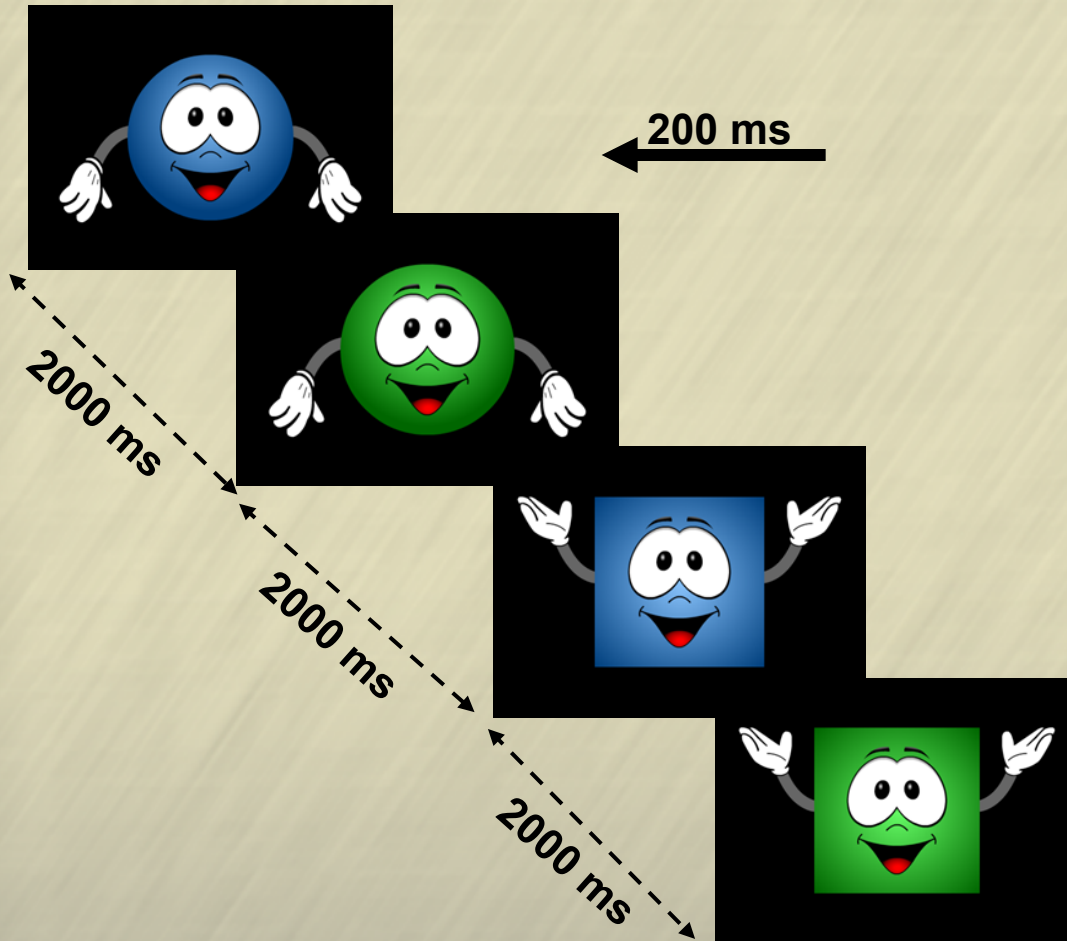
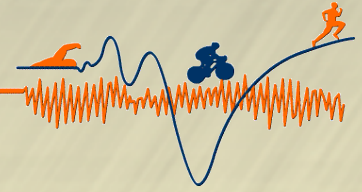


# Flanker Incongruent P3 Relationship with Attendance

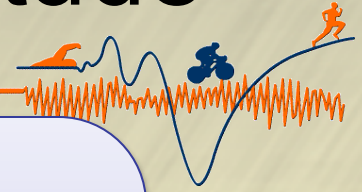




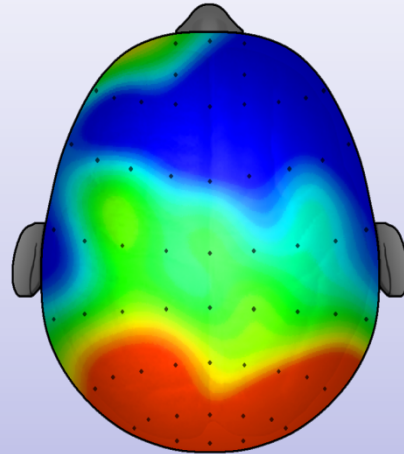
# Switch Task



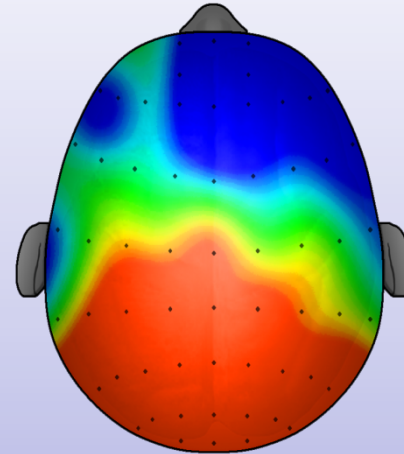
# Change in Switch P3 Amplitude



**FITKids**  
Intervention

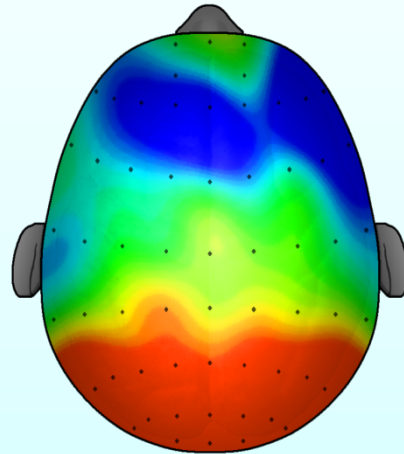


Pretest

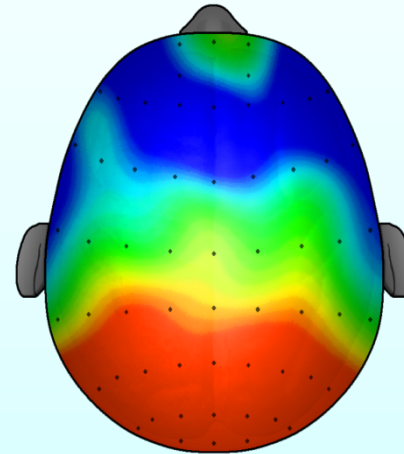


Posttest

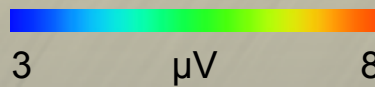
**Waitlist**  
Control



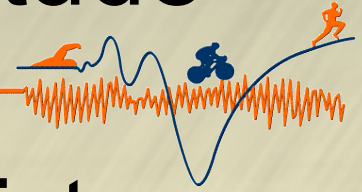
Pretest



Posttest

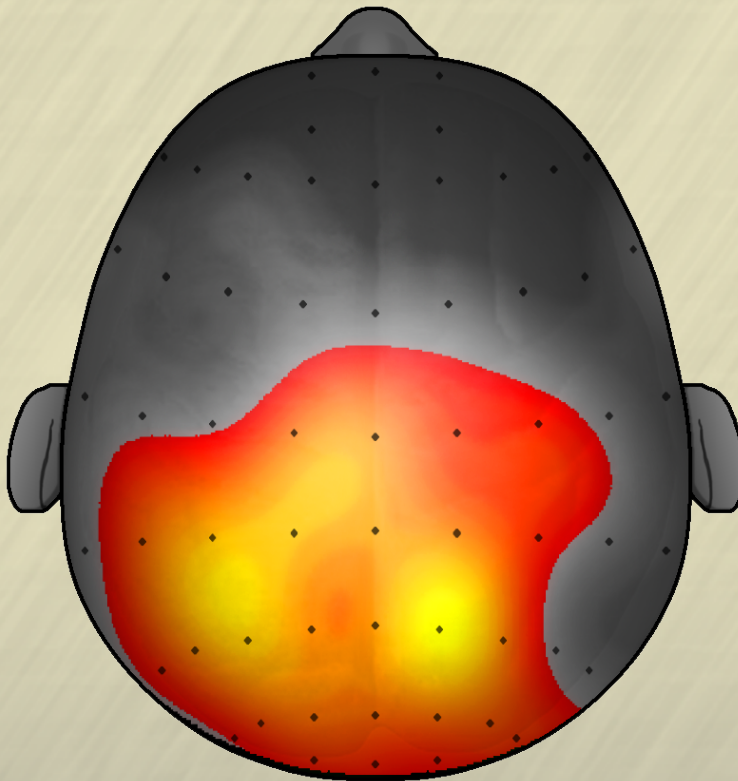


# Change in Switch P3 Amplitude



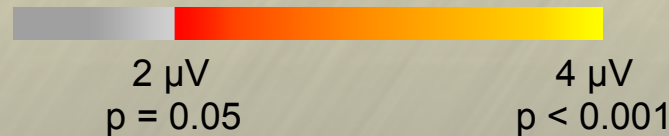
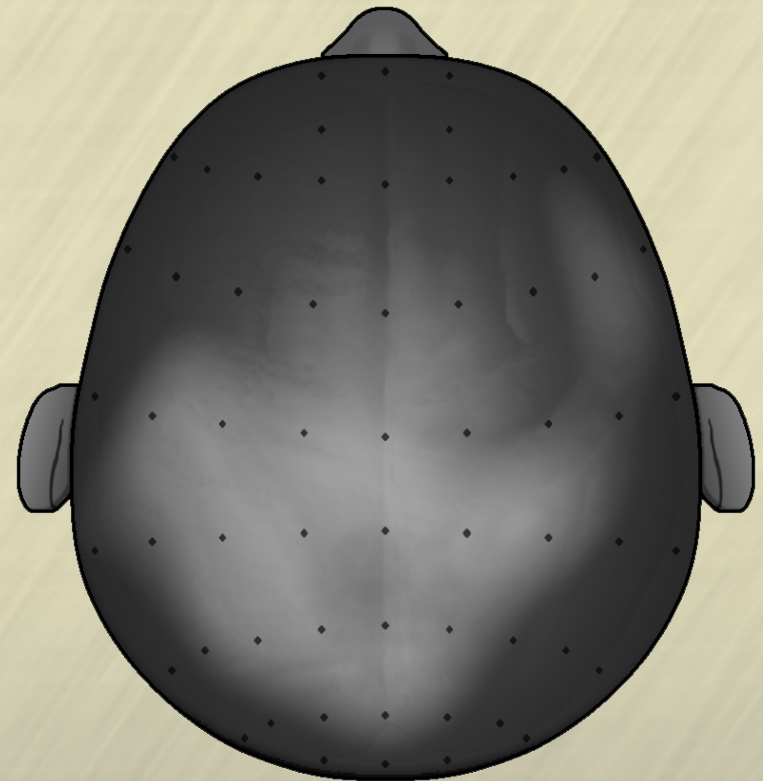
## FITKids

Intervention

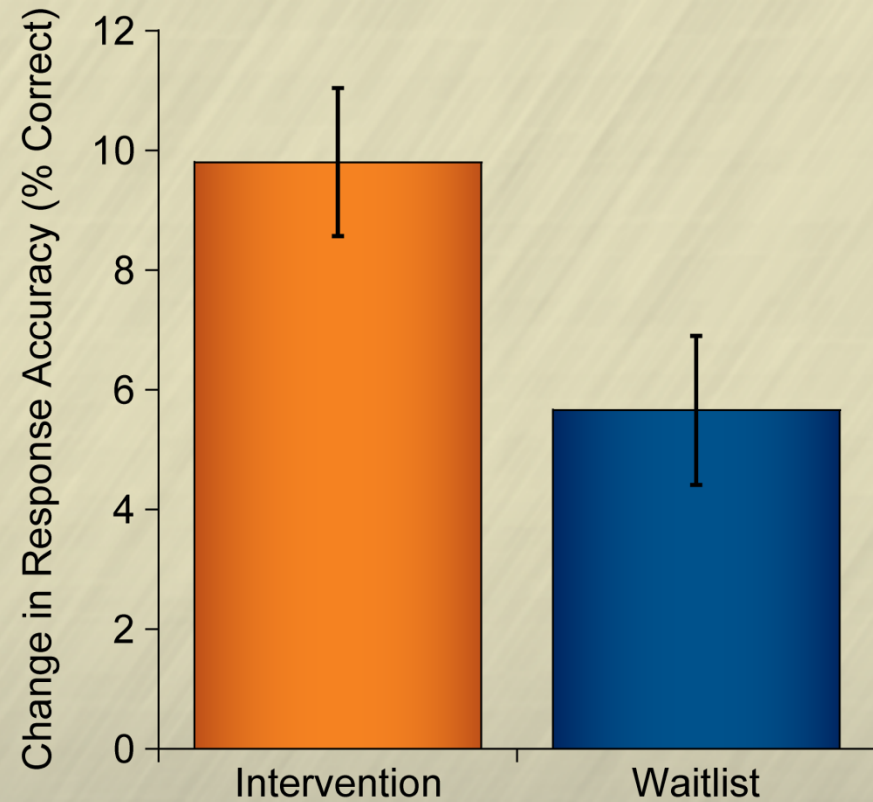
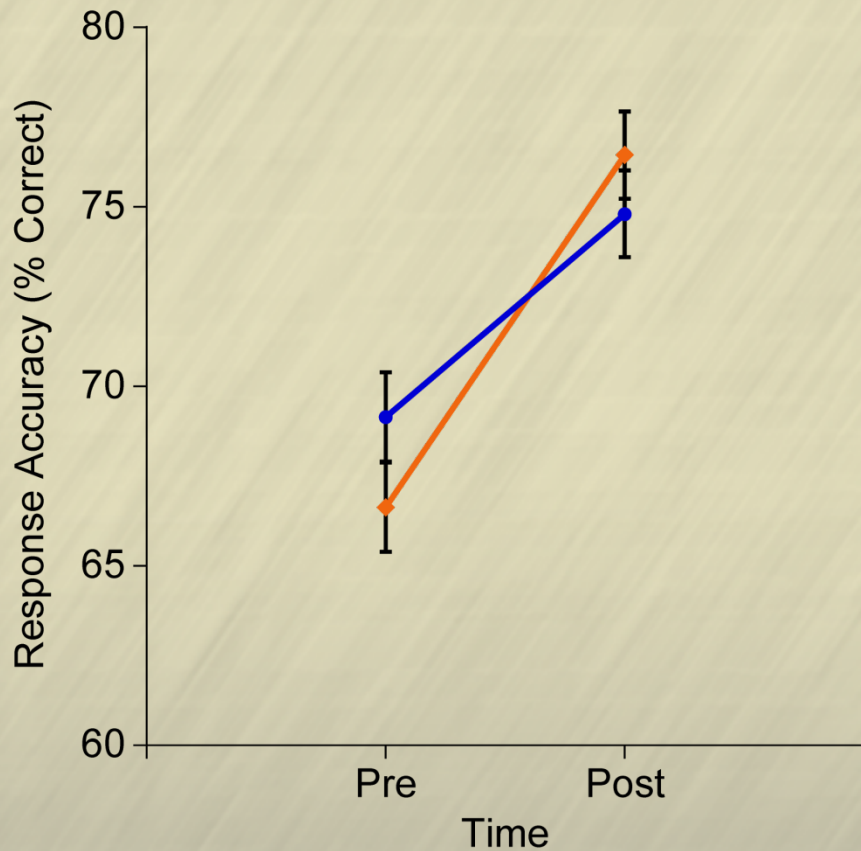
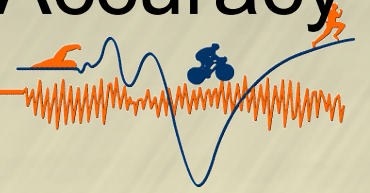


## Waitlist

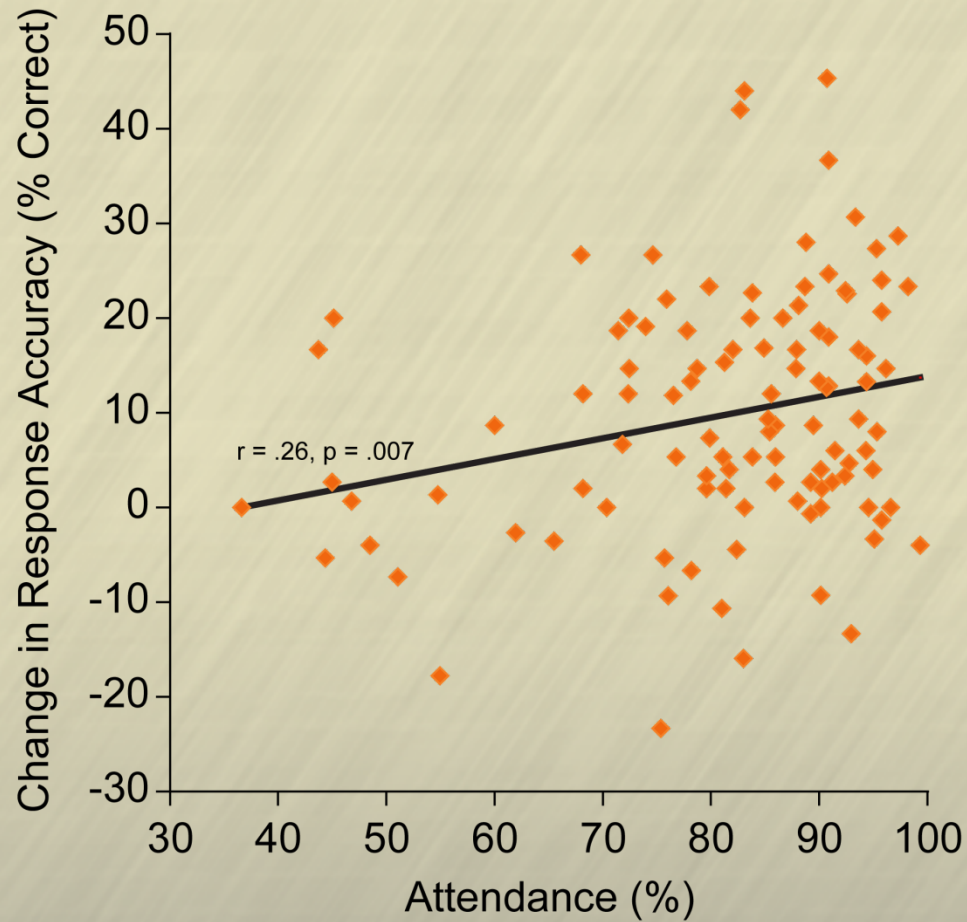
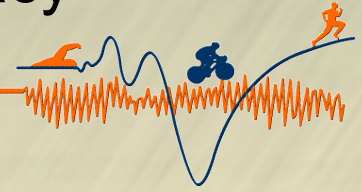
Control



# Change in Heterogeneous Response Accuracy

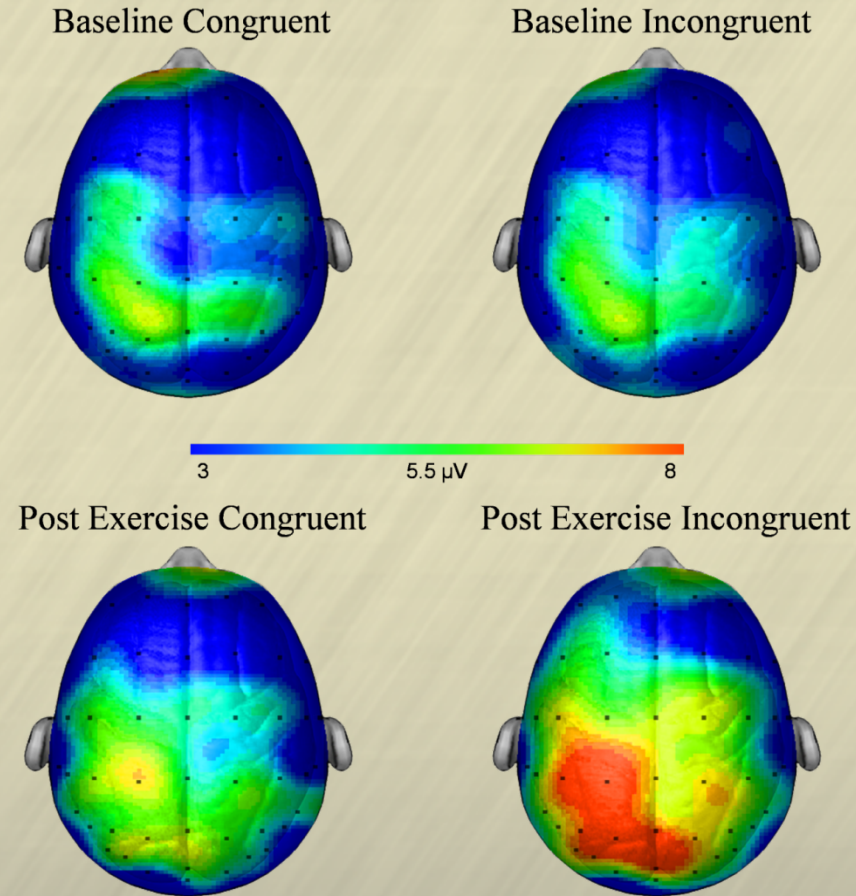
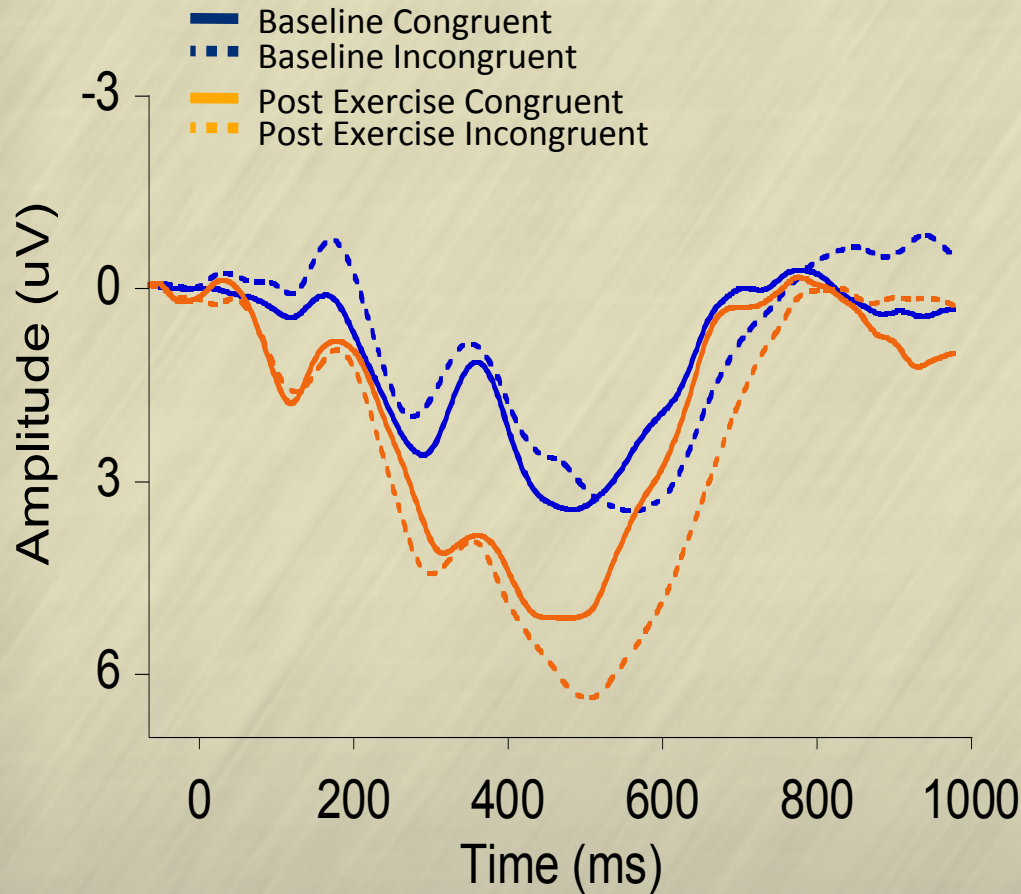
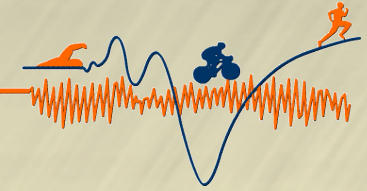


# Switch Heterogeneous Response Accuracy Relationship with Attendance

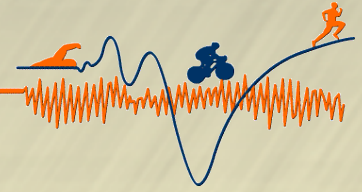


# Acute Exercise

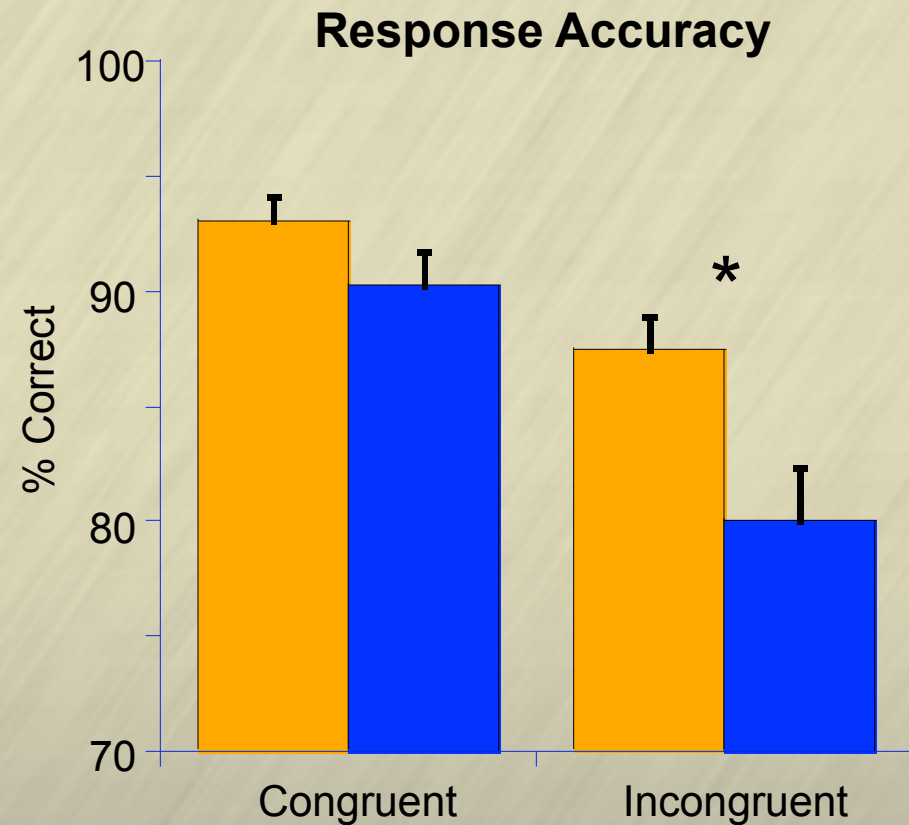
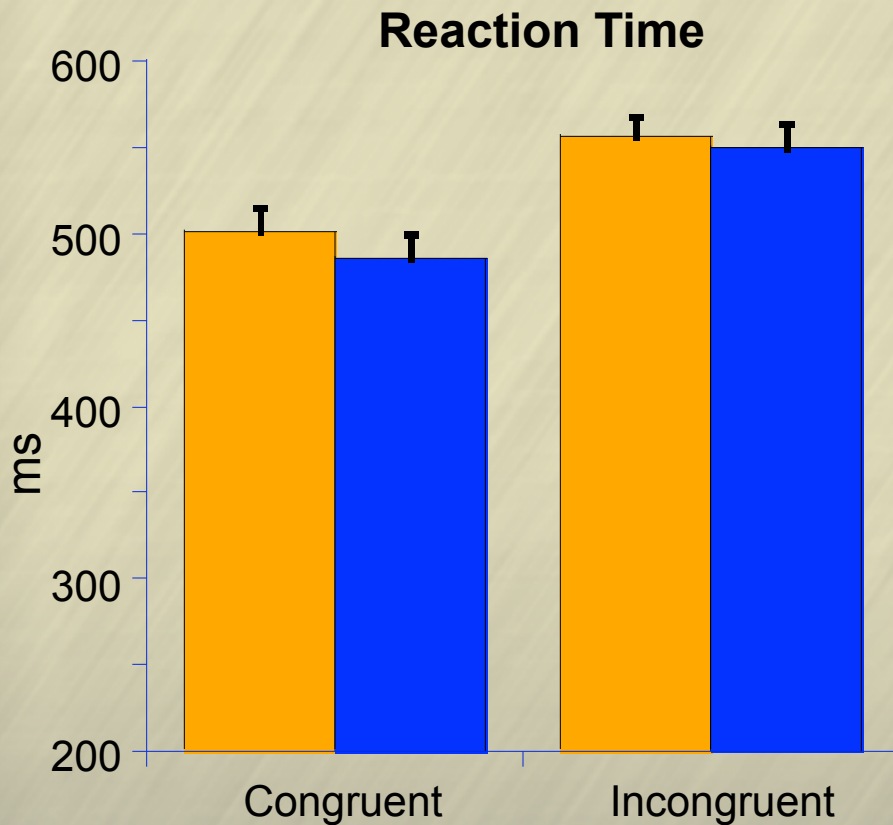
# Acute Exercise in Preadolescent Children



# Task Performance

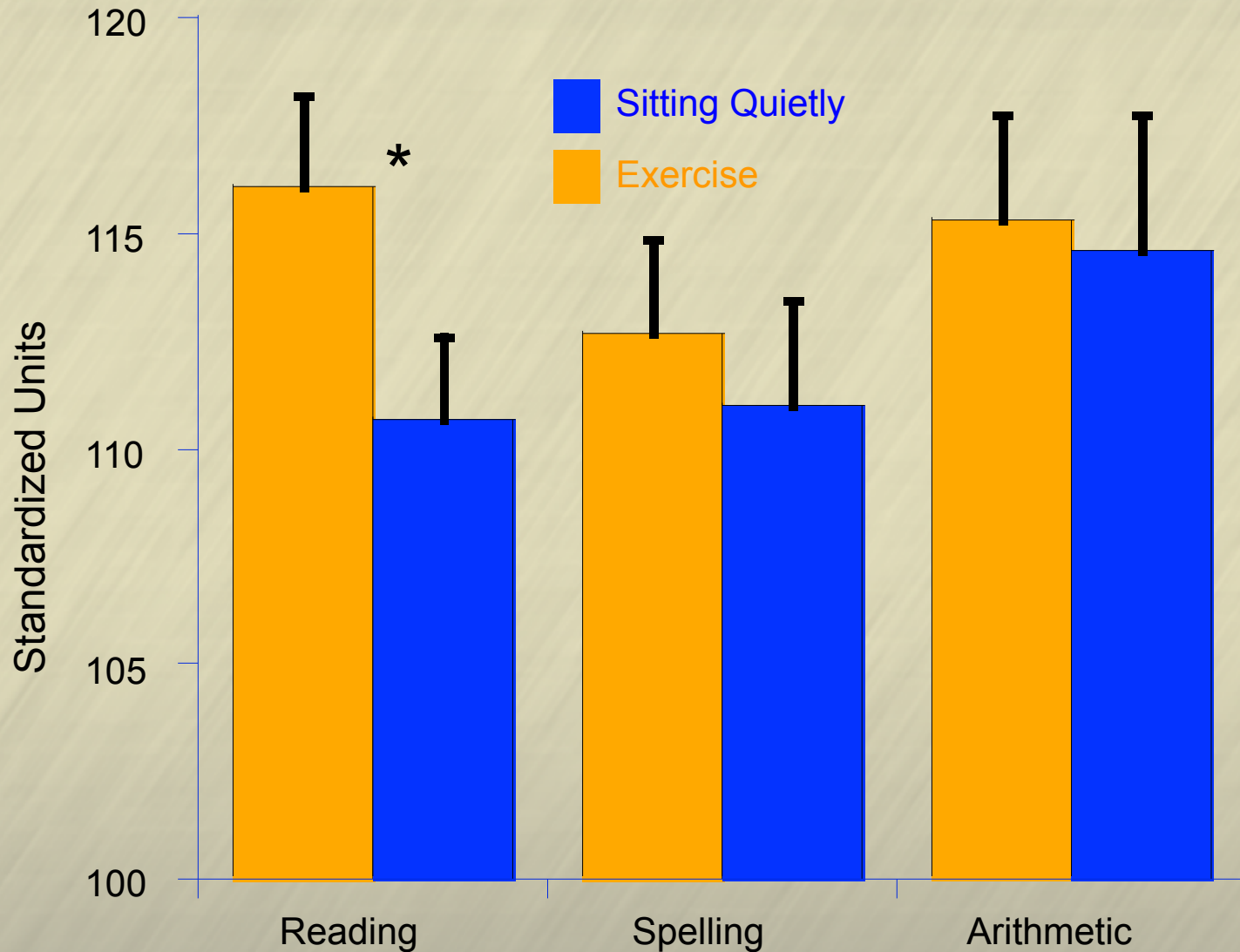
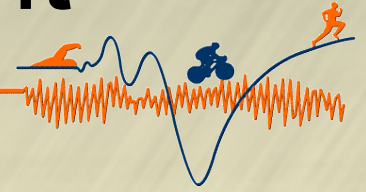


■ Sitting Quietly  
■ Exercise

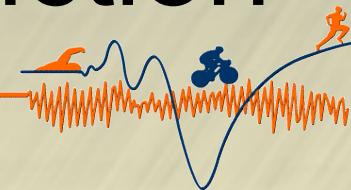




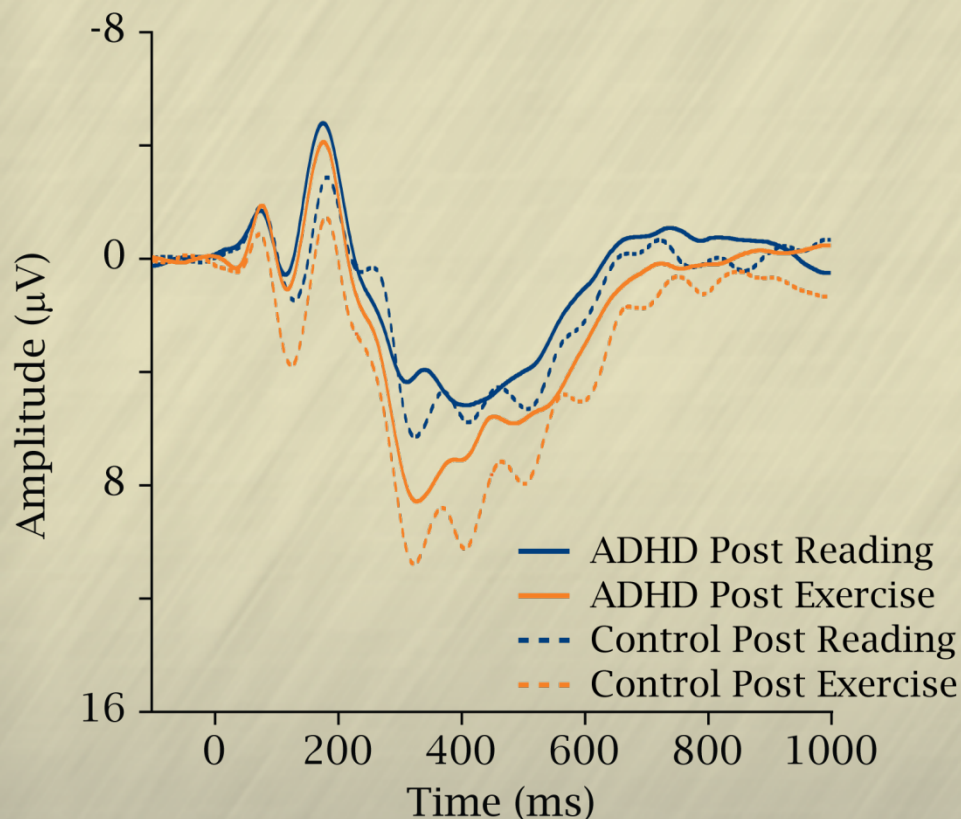
# Academic Achievement



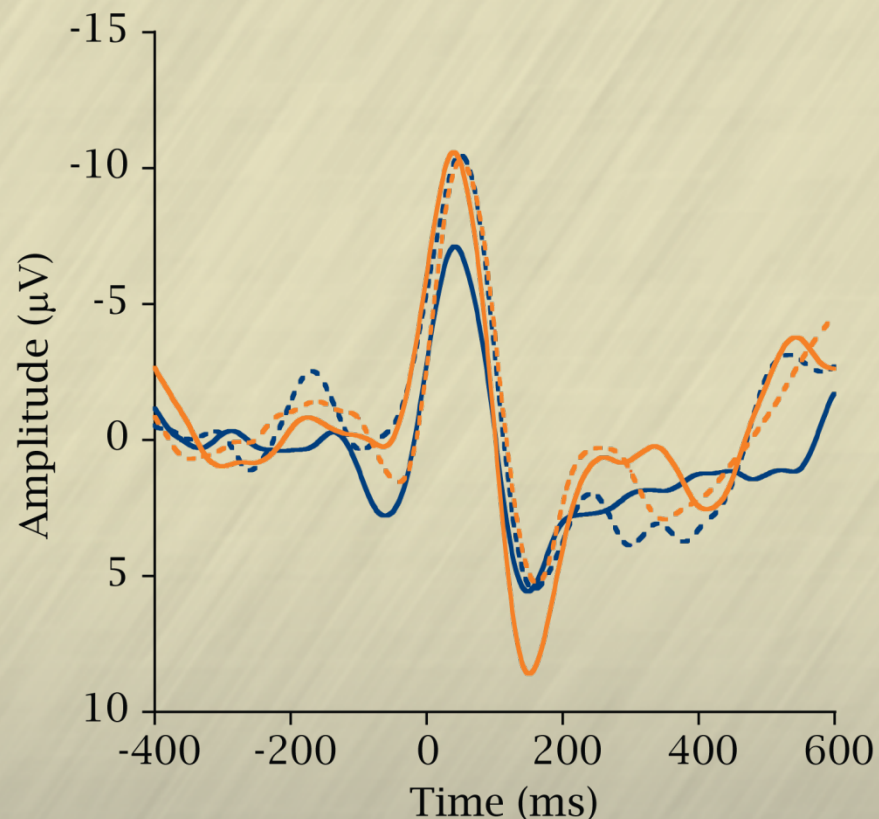
# ADHD & Neuroelectric Function



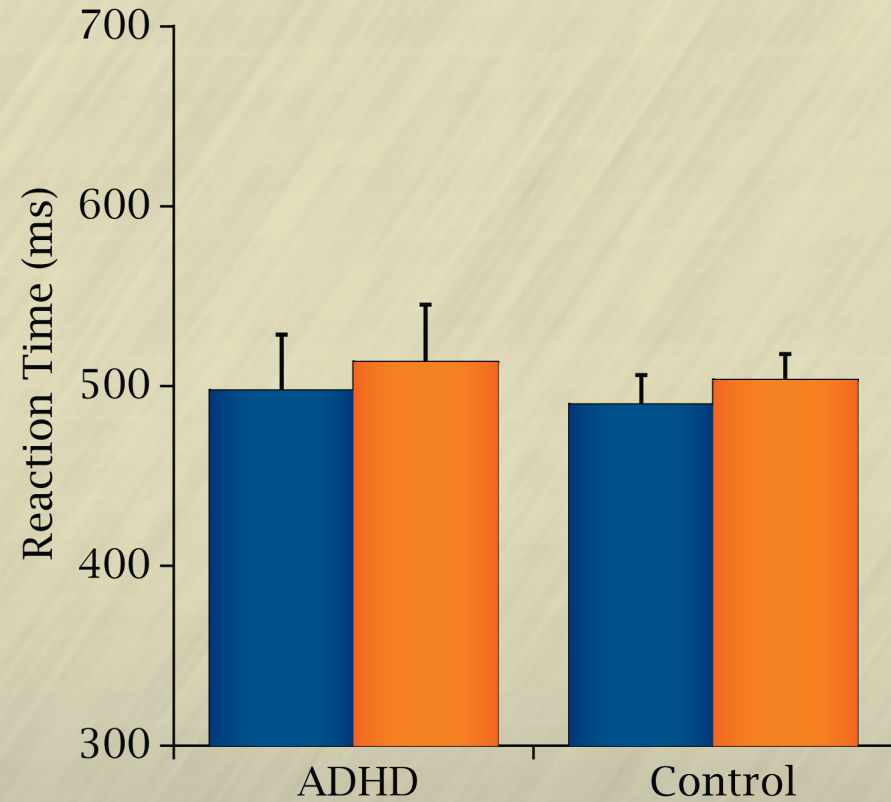
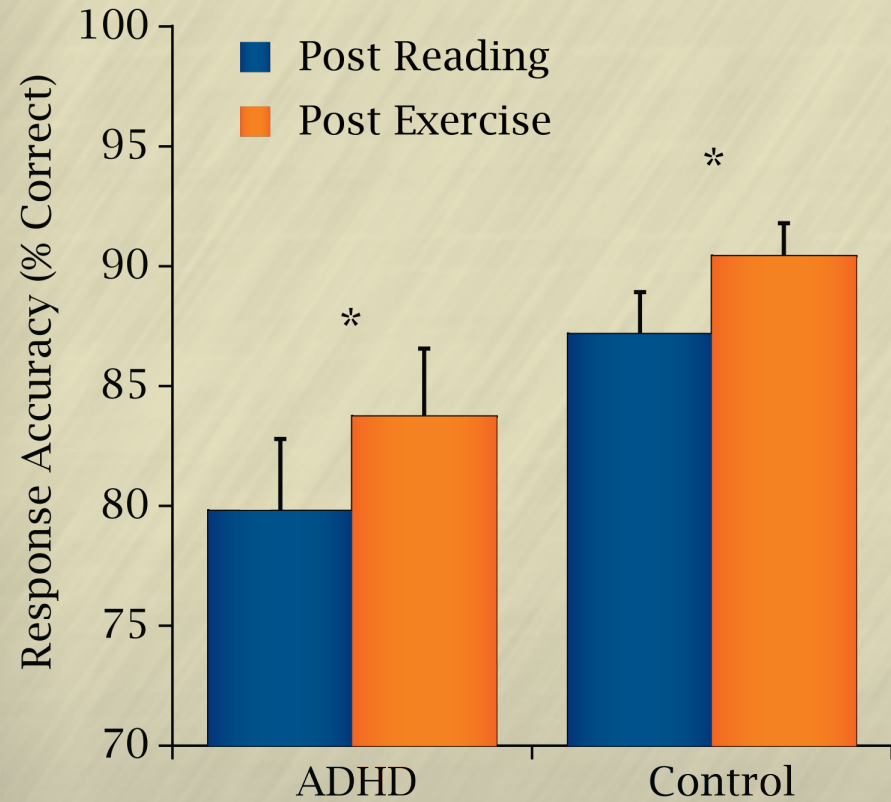
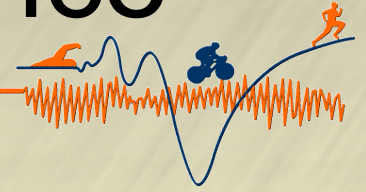
P3



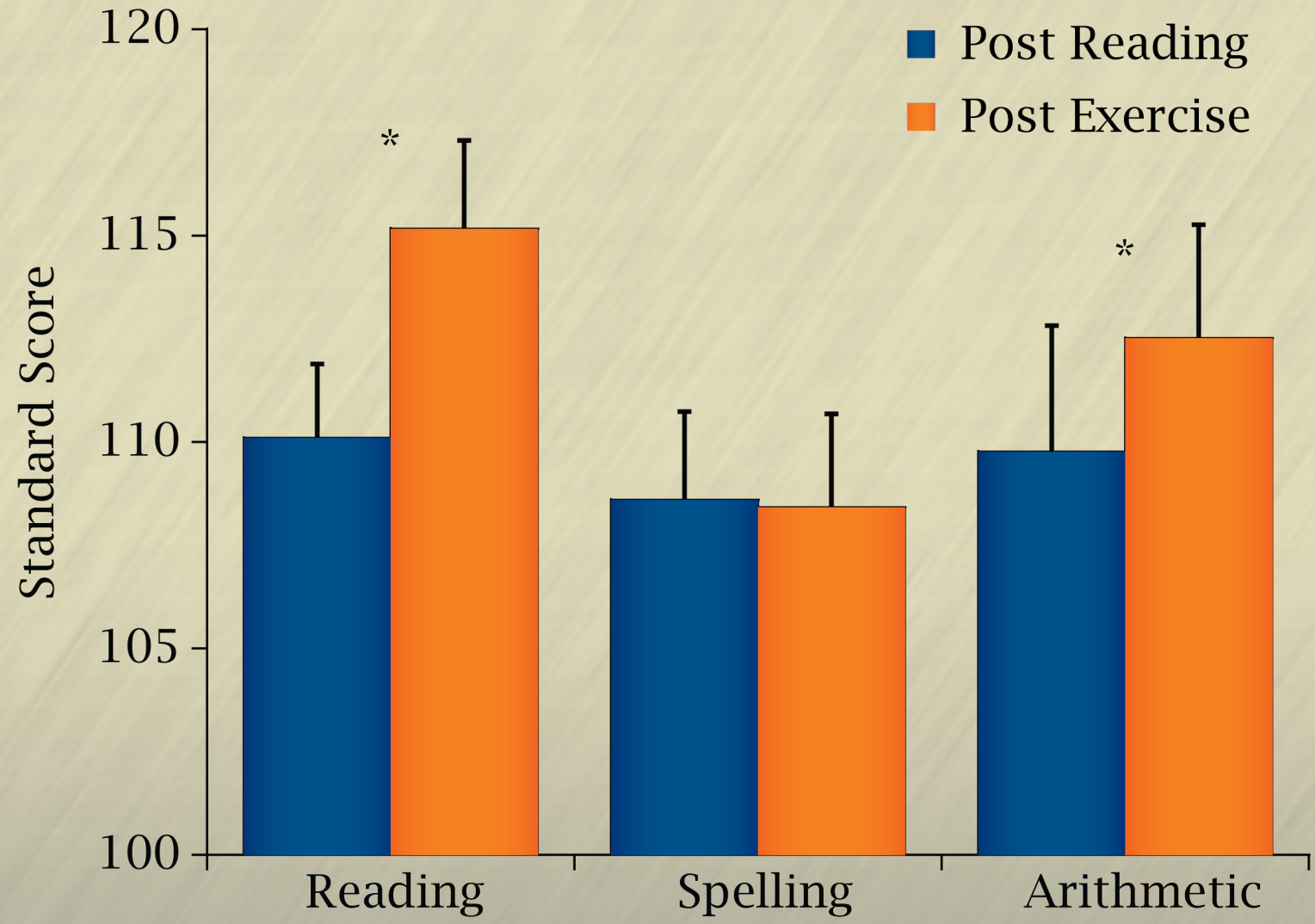
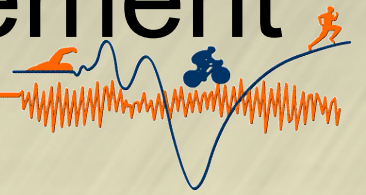
ERN



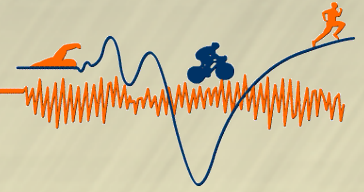
# ADHD & Task Performance



# ADHD & Academic Achievement



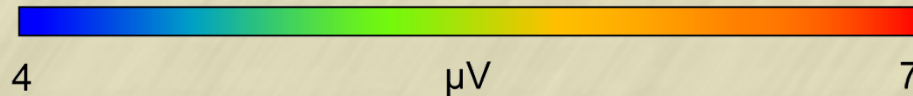
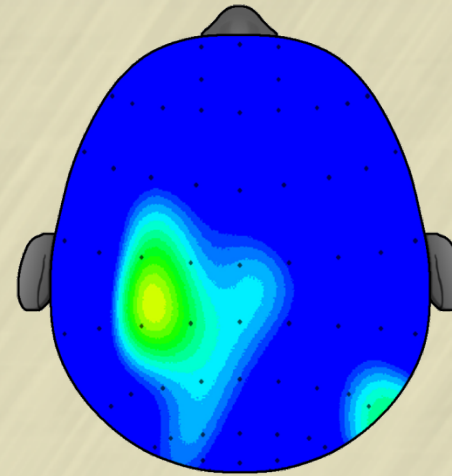
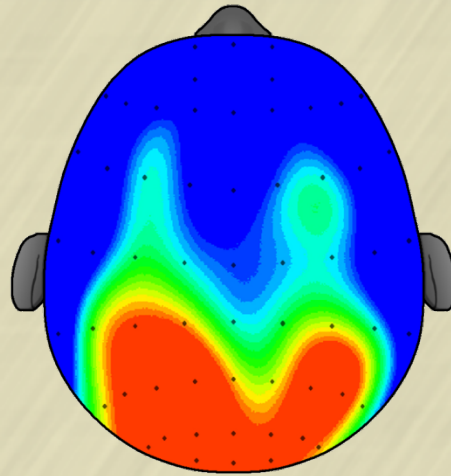
# Individual Differences in Inhibitory Control



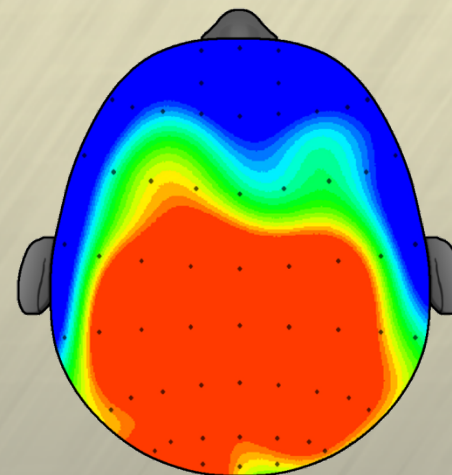
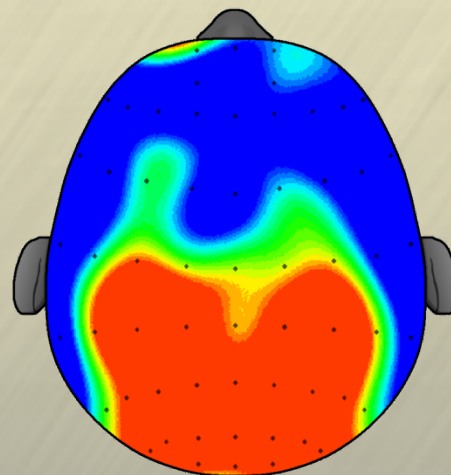
Higher Performers

Lower Performers

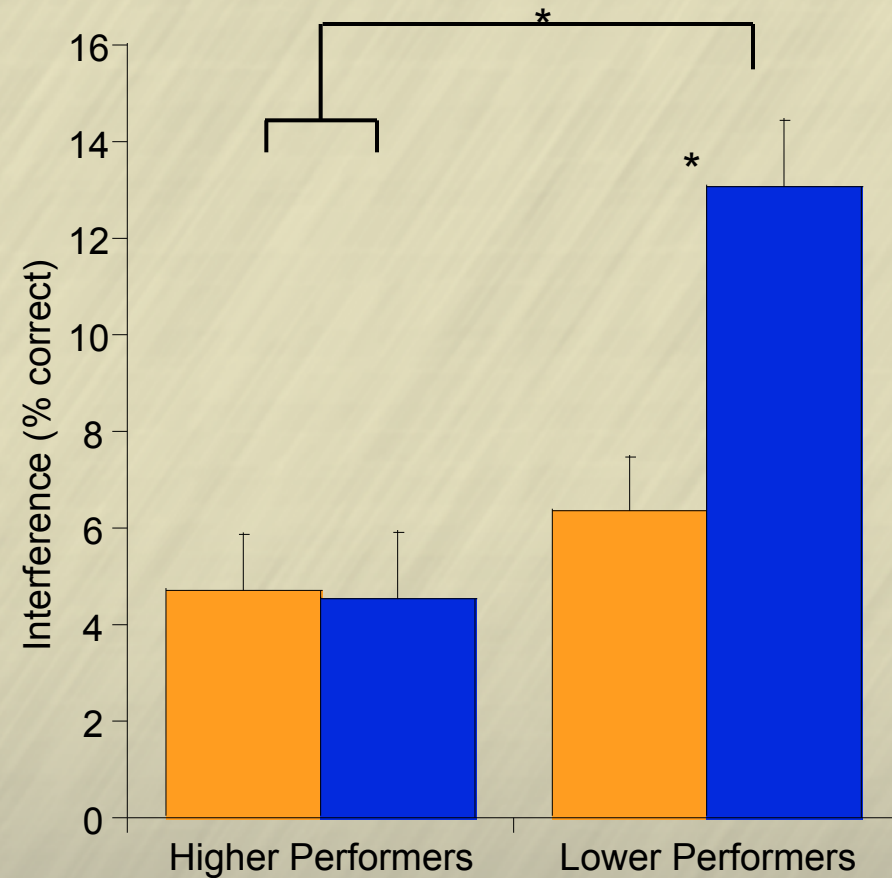
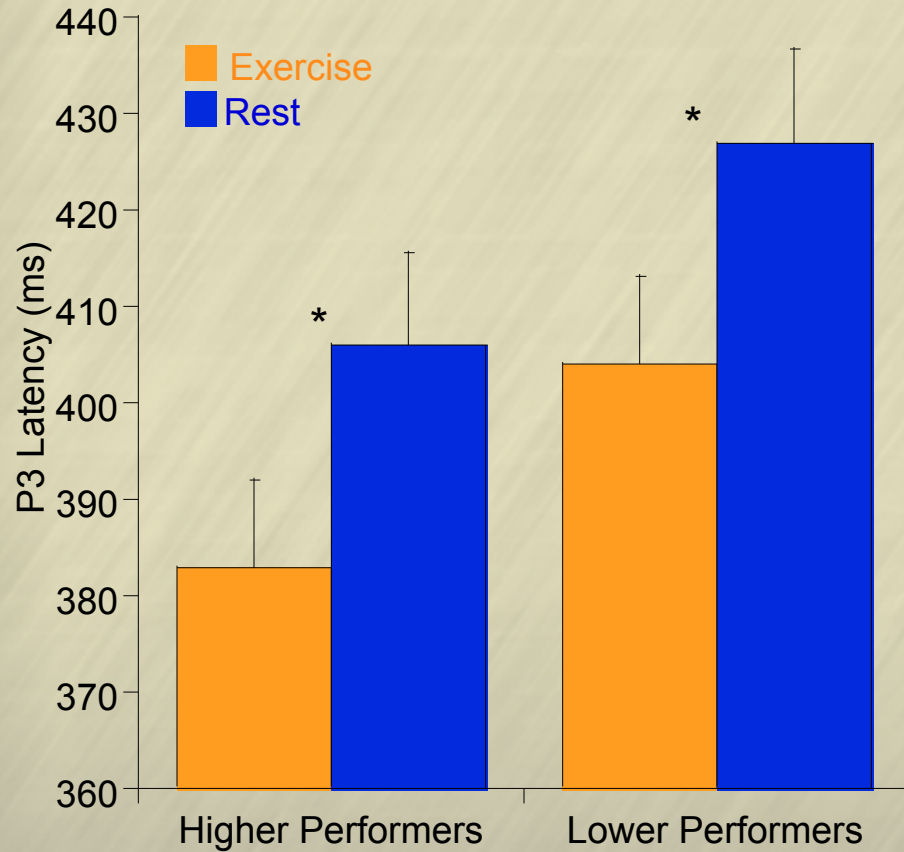
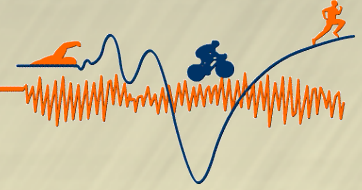
Rest



Exercise



# Individual Differences in Inhibitory Control

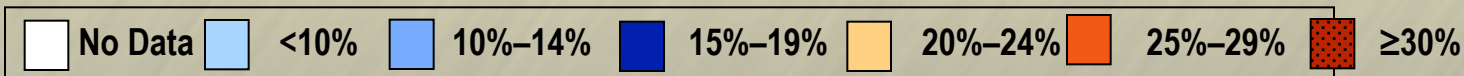
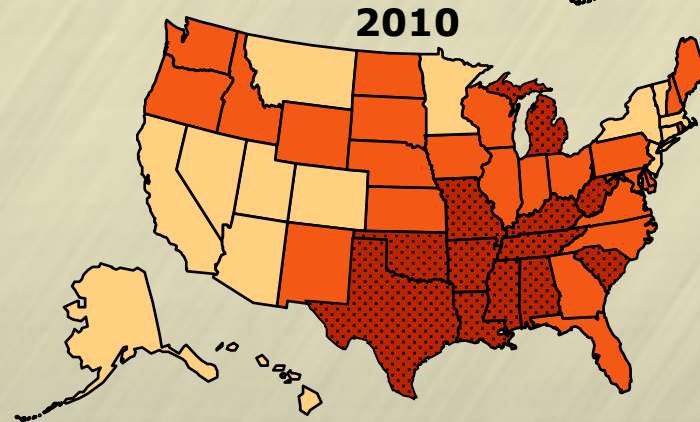
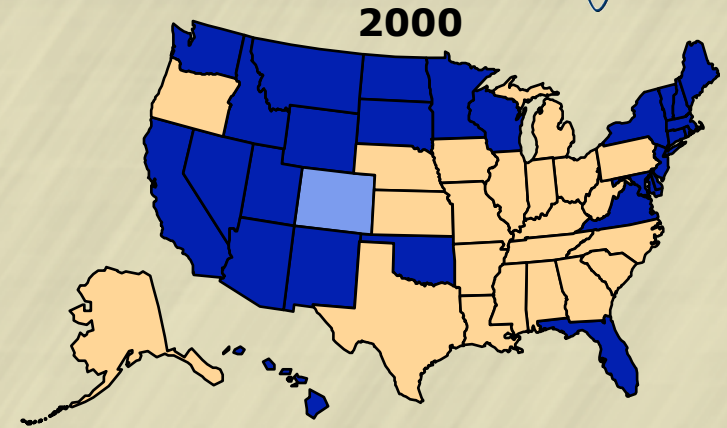
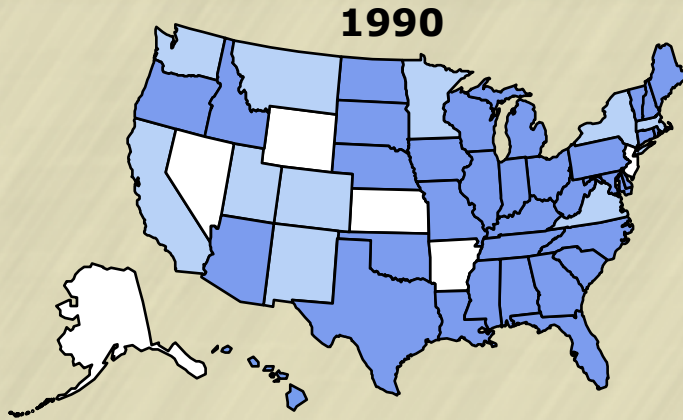
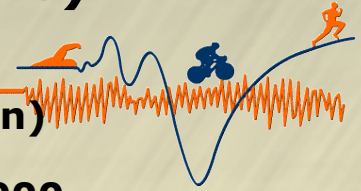


# Adiposity

# Obesity Trends\* Among U.S. Adults (CDC)

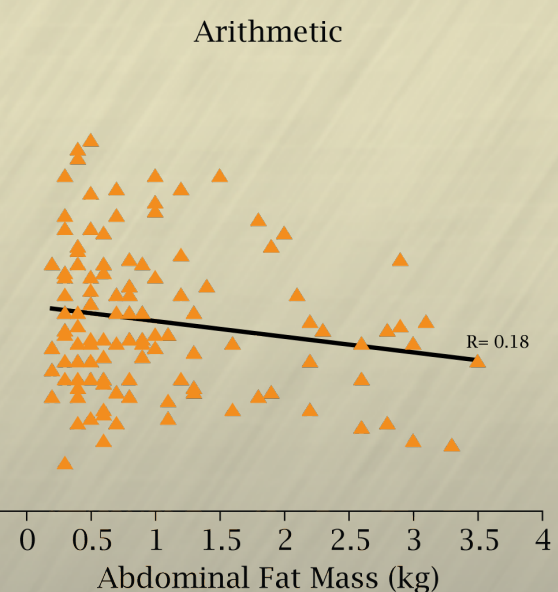
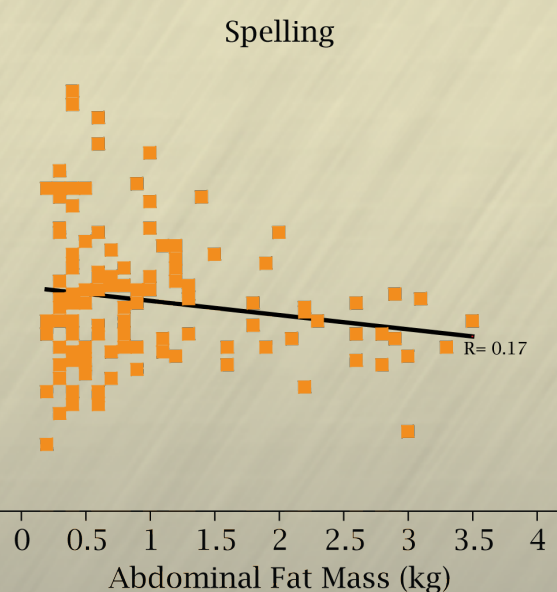
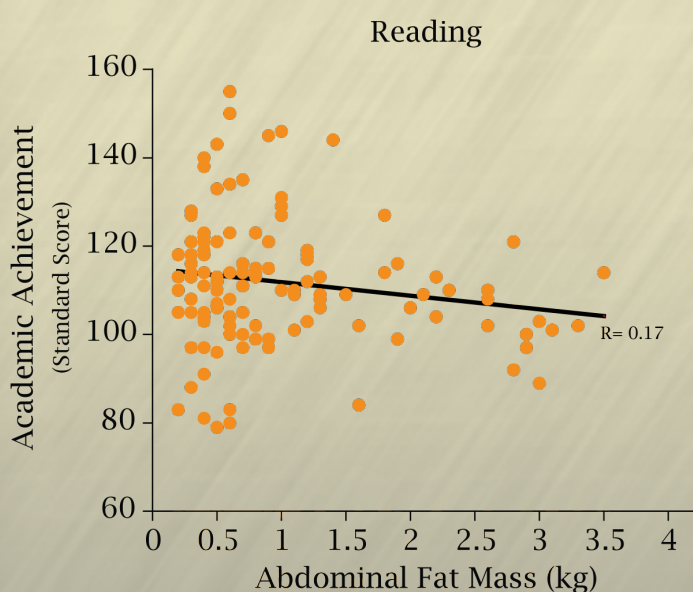
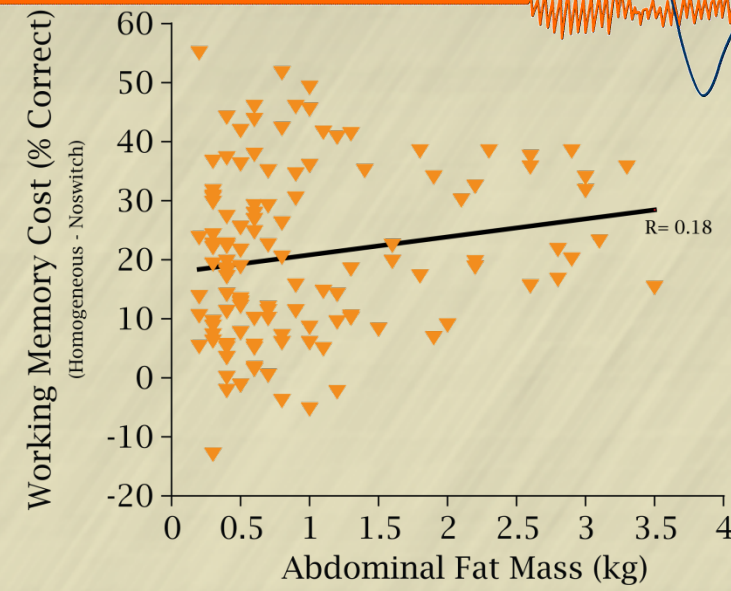
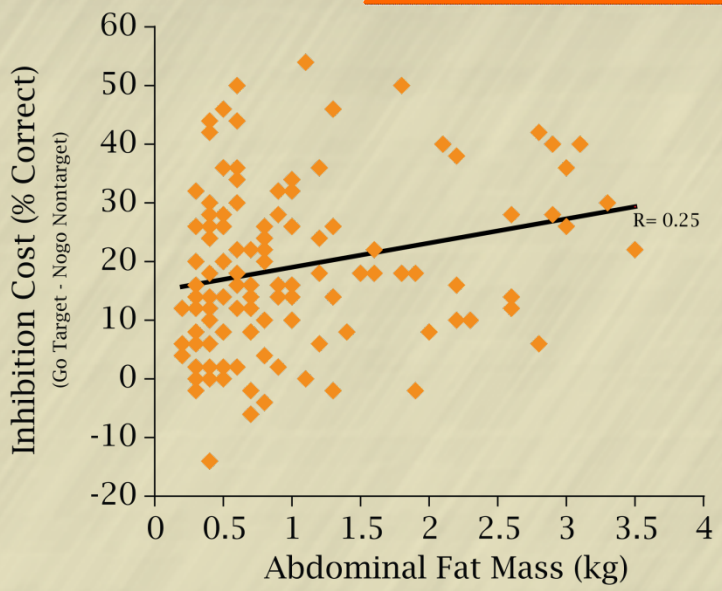
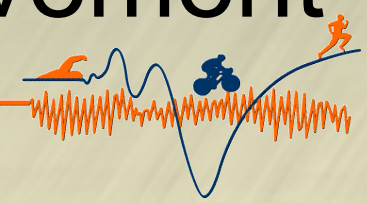
## BRFSS, 1990, 2000, 2010

(\*BMI  $\geq 30$ , or about 30 lbs. overweight for 5' 4" person)

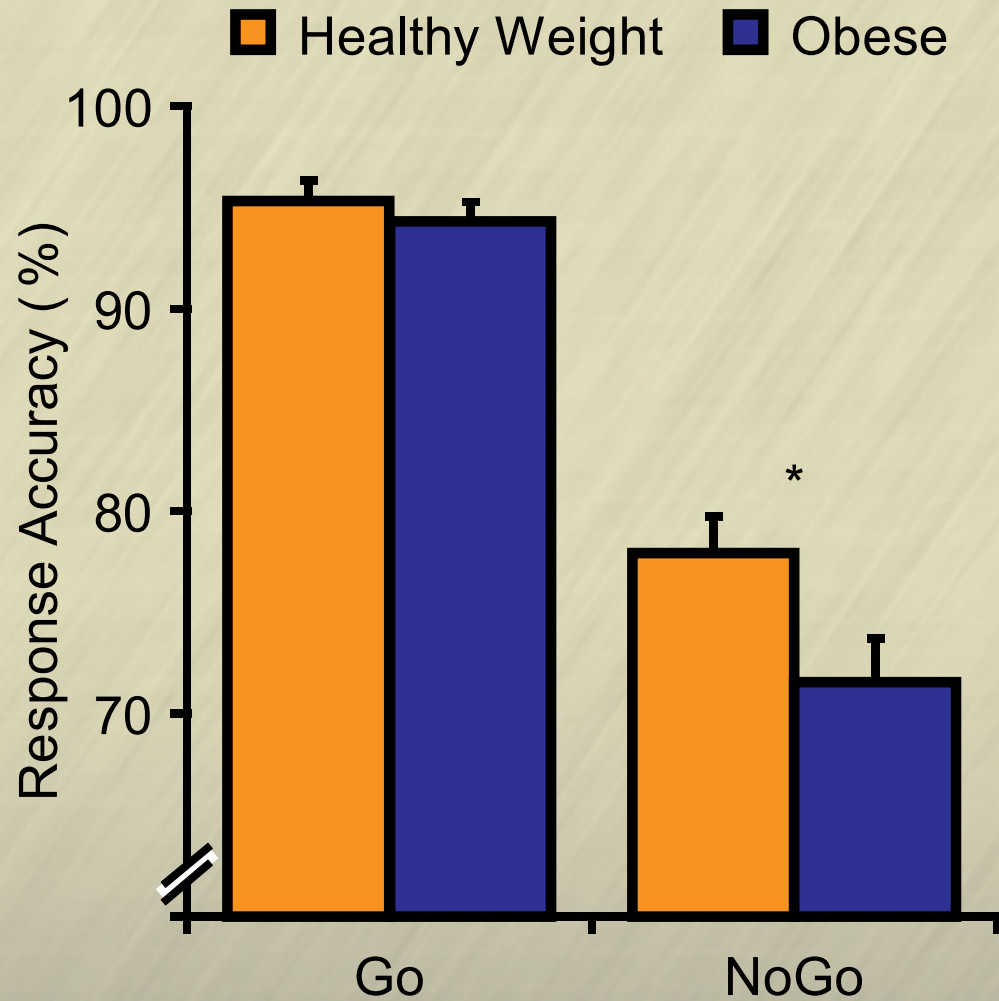
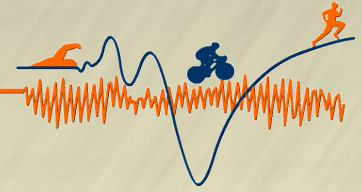




# Adiposity, Cognition, & Achievement

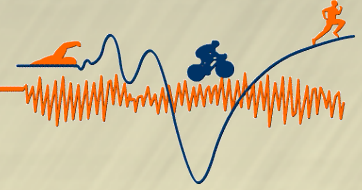


# Obesity & Inhibition

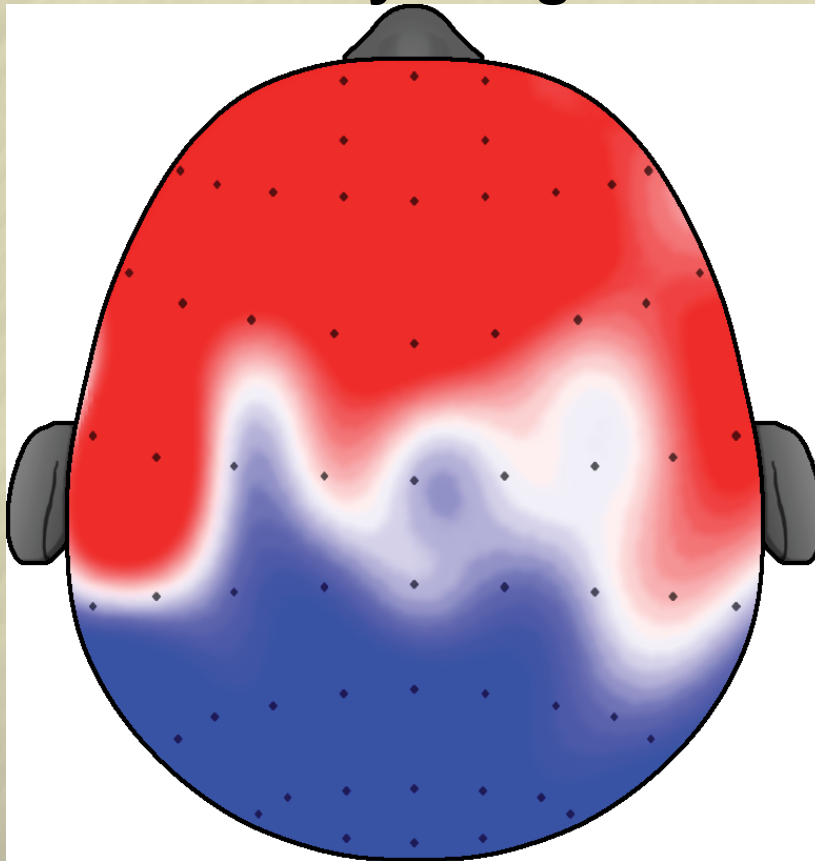


# Obesity & ERPs

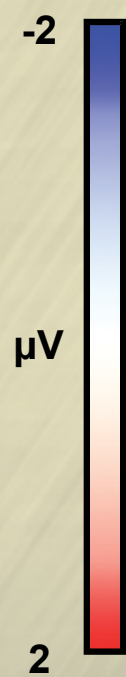
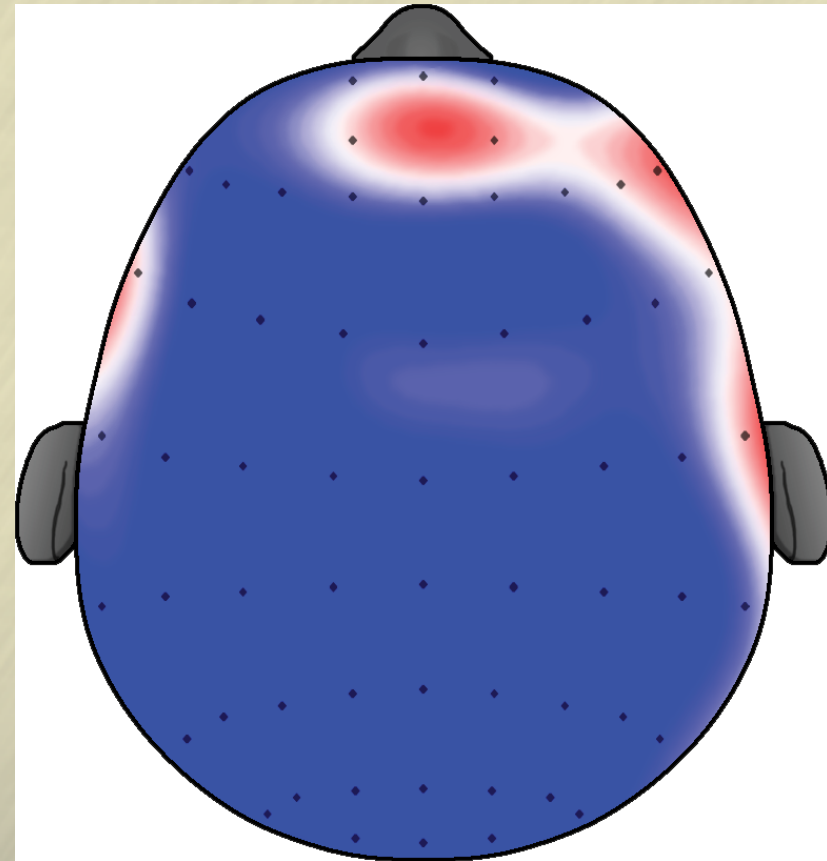
(NoGo-Go P3 Amplitude)



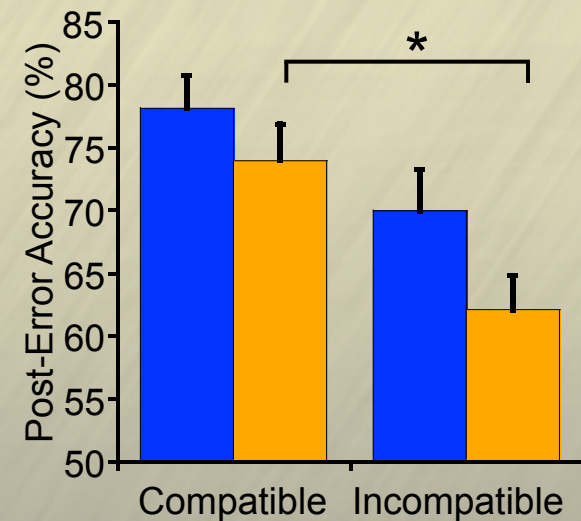
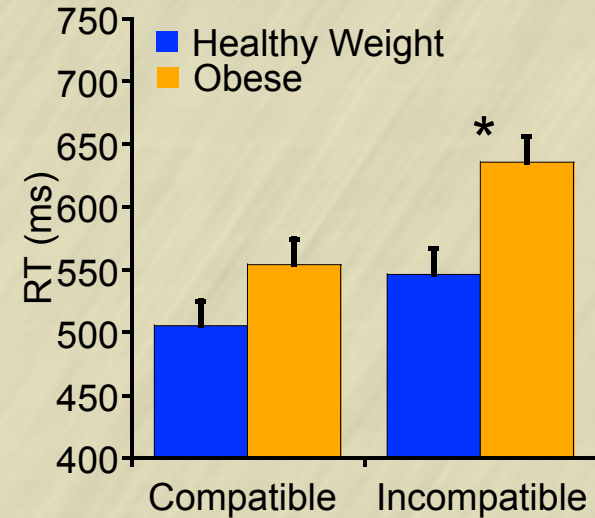
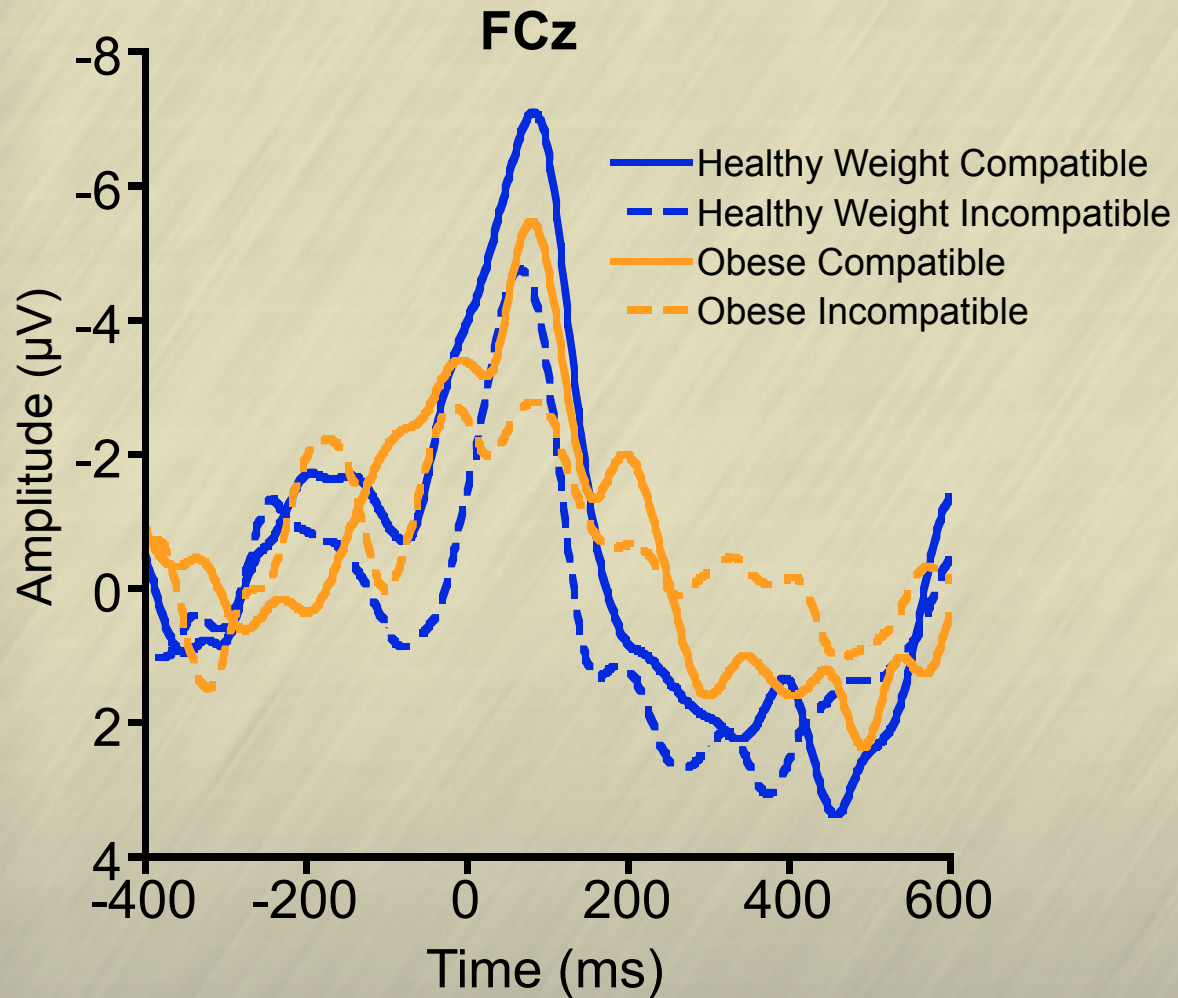
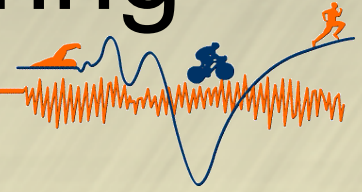
Healthy Weight



Obese

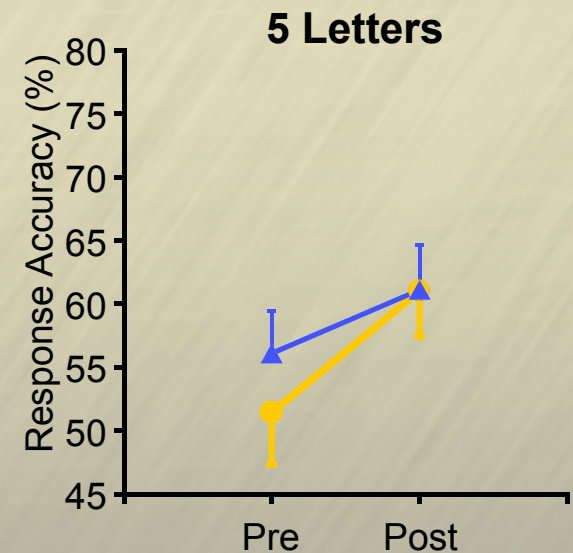
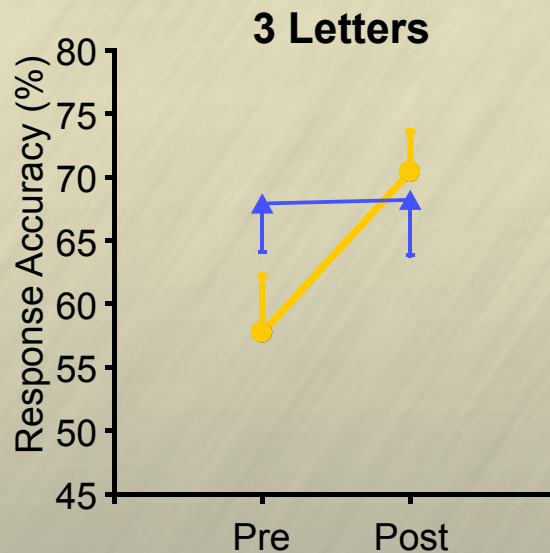
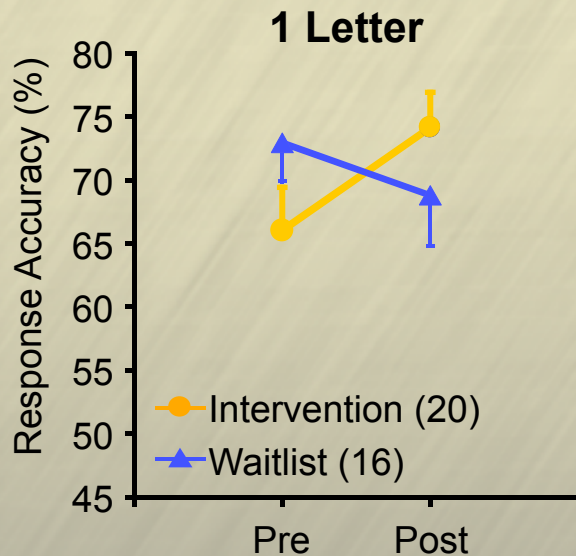
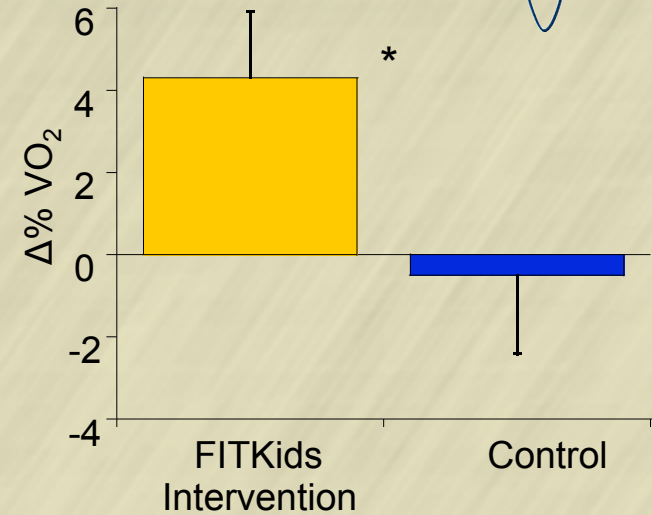
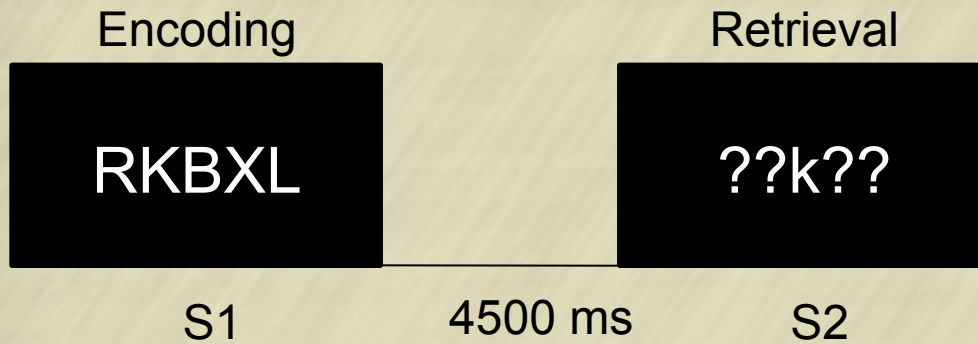
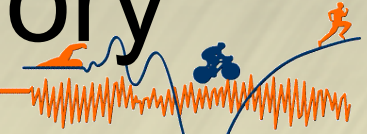


# Obesity & Action Monitoring

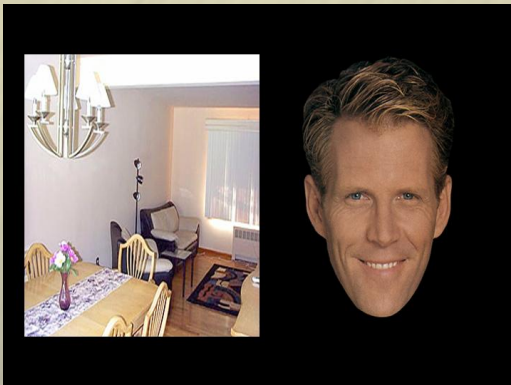


# Memory

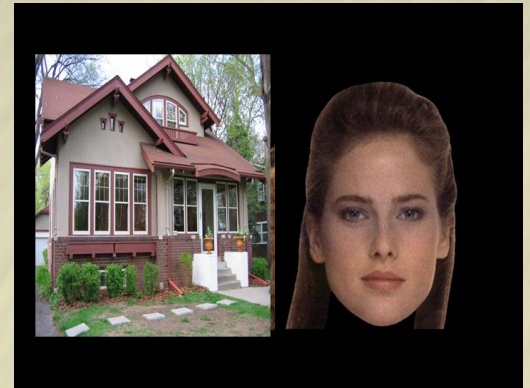
# Fitness & Working Memory



# Picture Encoding

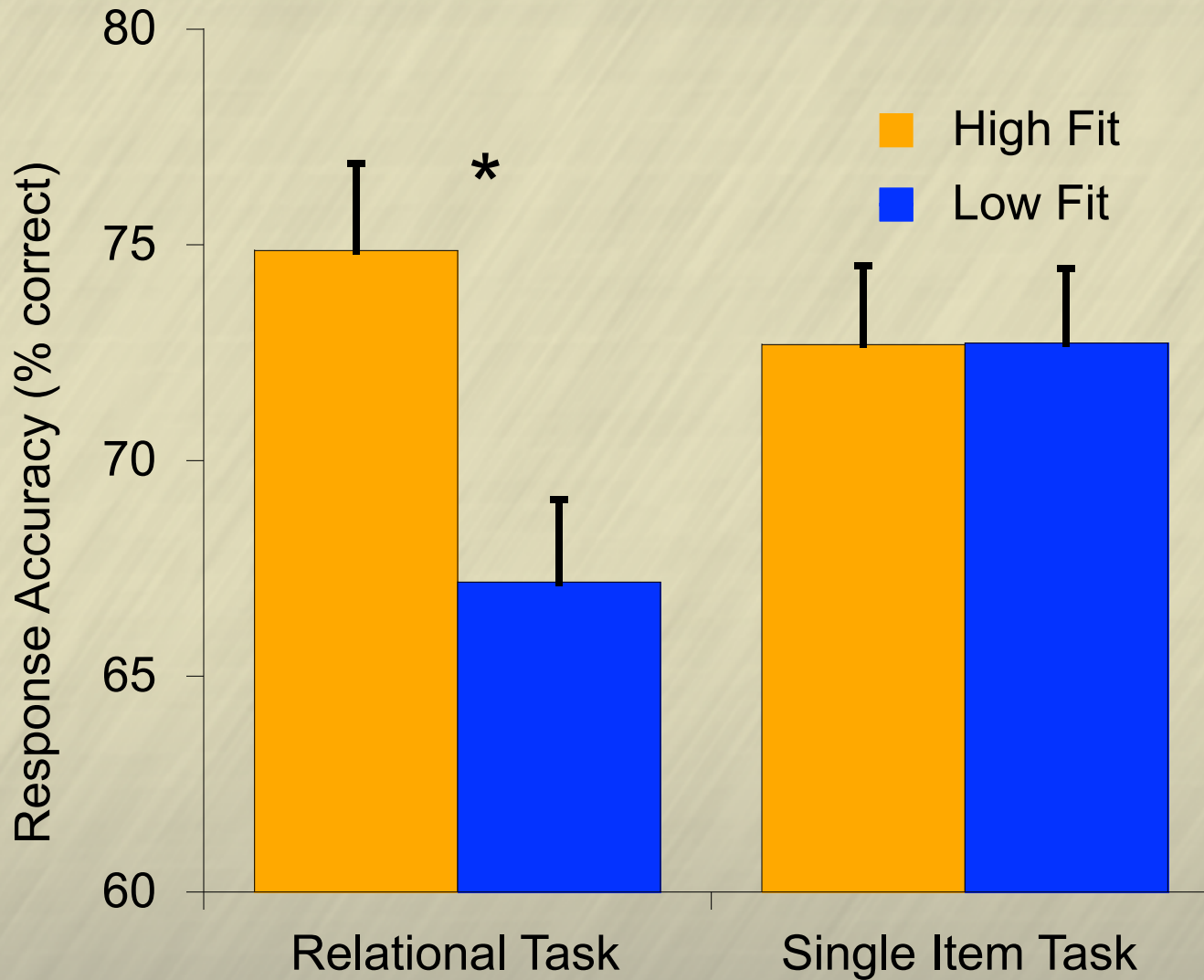
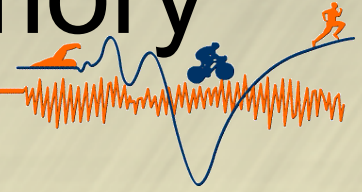


# Retrieval Task



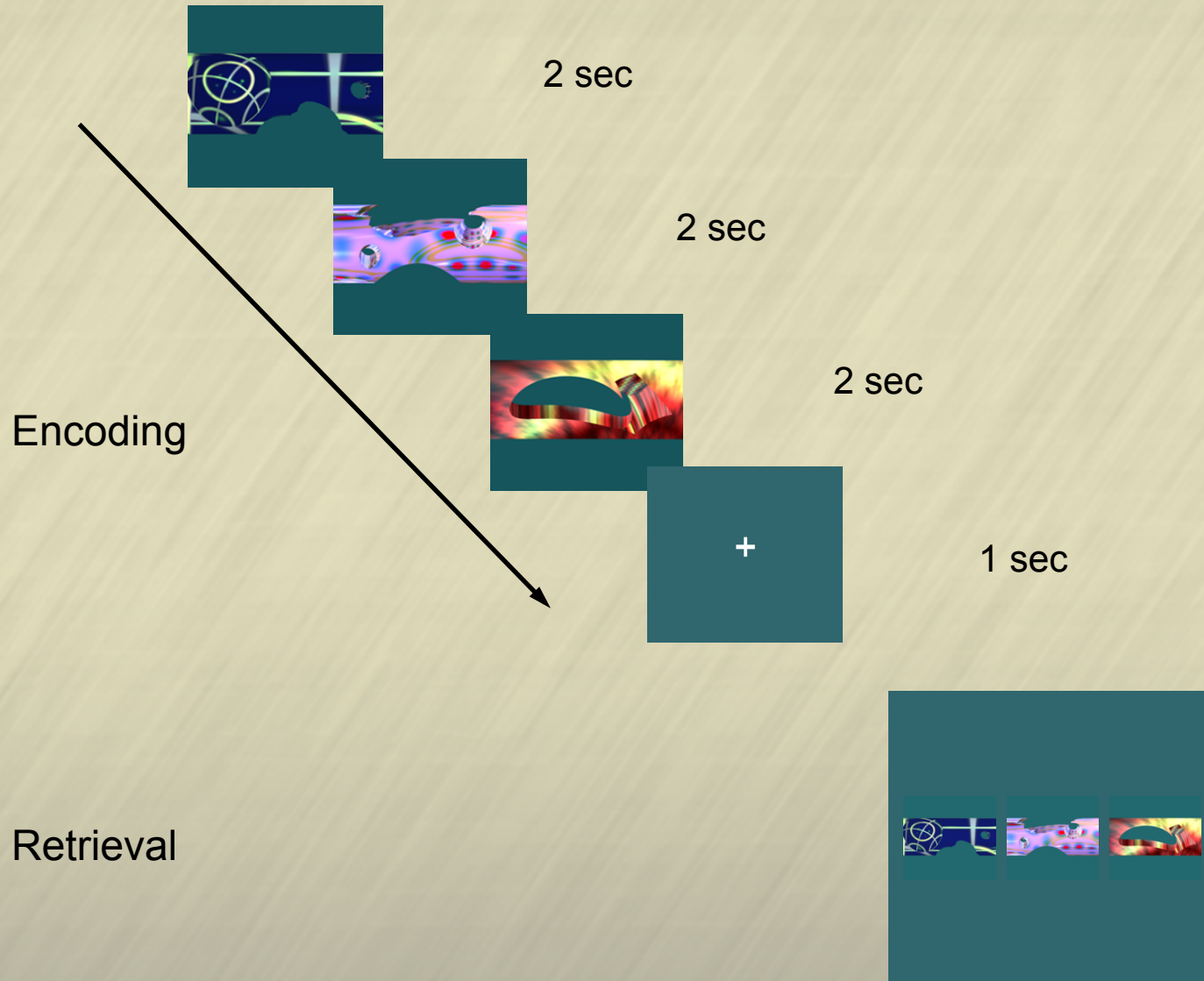
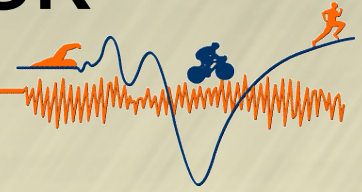
5 minute Delay

# Fitness & Relational Memory

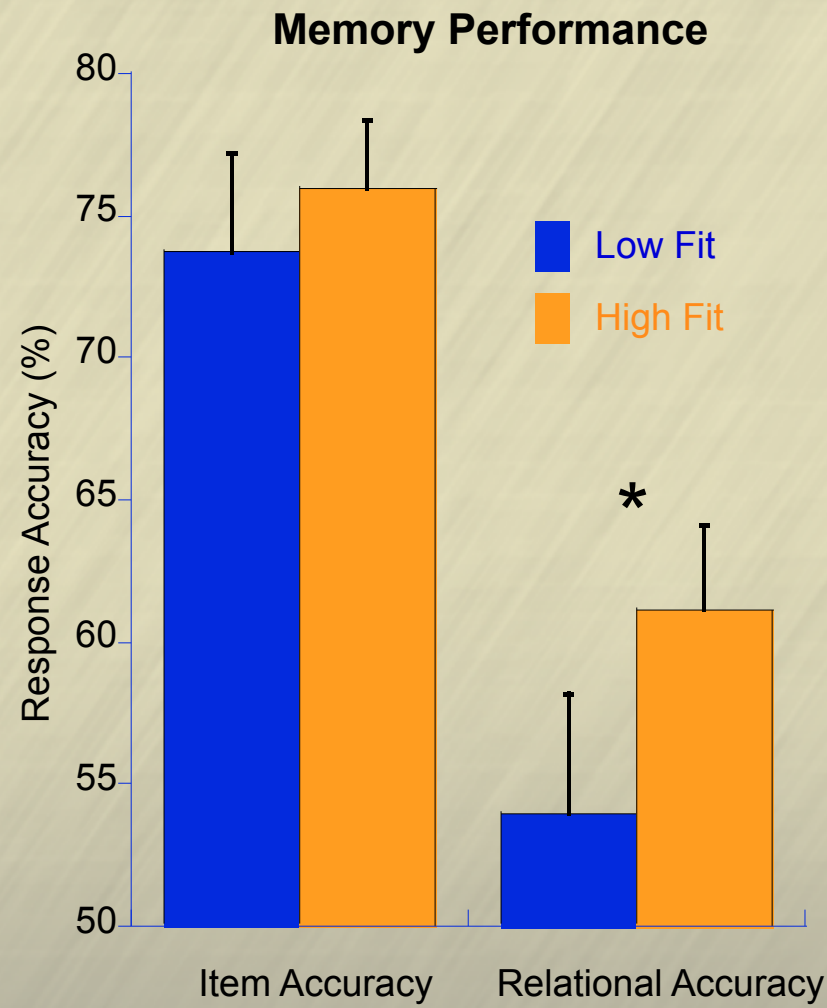
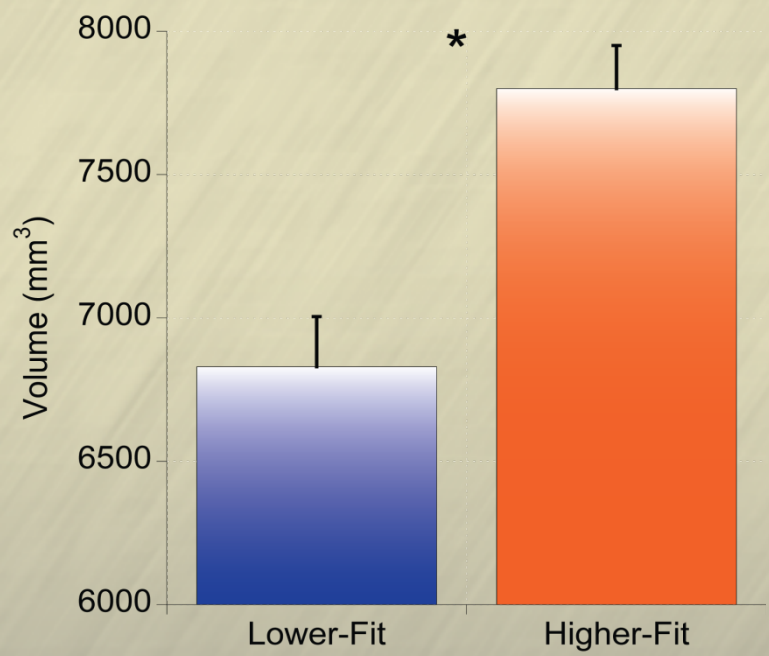
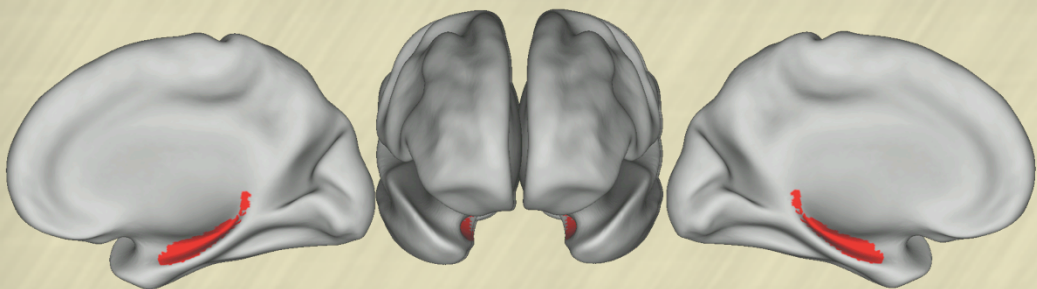
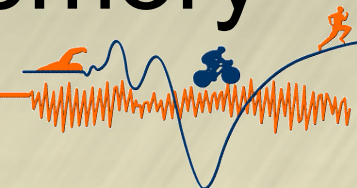




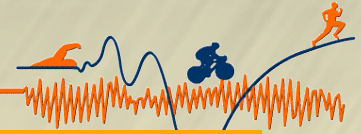
# Relational Memory Task



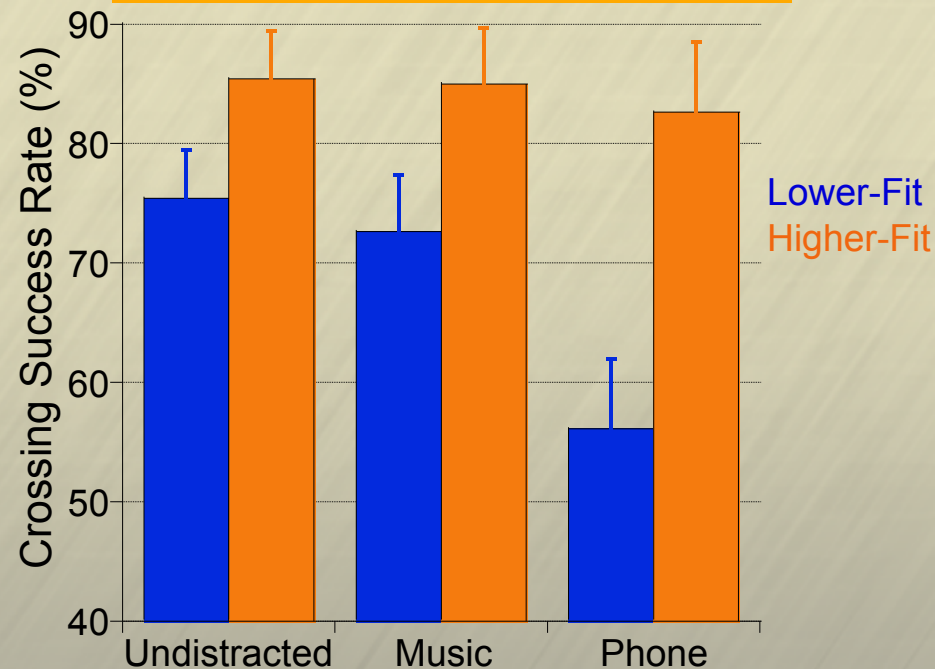
# Fitness, Hippocampus, & Memory



# Virtual Crosswalk

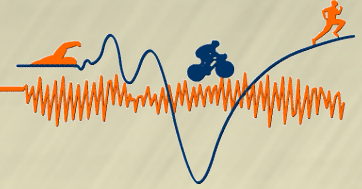


- Why do we care about attention and memory performance in children?
- Motor vehicle accidents are among the leading causes of death among children under the age of 16 years in the U.S.
- Given the importance of fitness to cognition, might fitness lead to better decision making at the crosswalk?



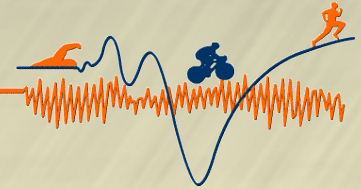
# Conclusions

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- Fitness may benefit brain health and academic performance.
- Fitness has been linked to changes in cognition that are disproportionately larger for tasks requiring cognitive control.
- Early PA experience may shape cognition and its neural underpinnings.
- Excess adiposity is related to decrements in cognitive & brain health, and scholastic achievement.
- Single bouts of aerobic exercise benefit basic and applied aspects of cognitive performance.
- Collectively, these data suggest that time spent engaged in physically active does not detract from academic performance.
- Thus, early intervention is crucial toward lifespan health and effective function of brain and cognition.

# Acknowledgements



## Collaborators

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