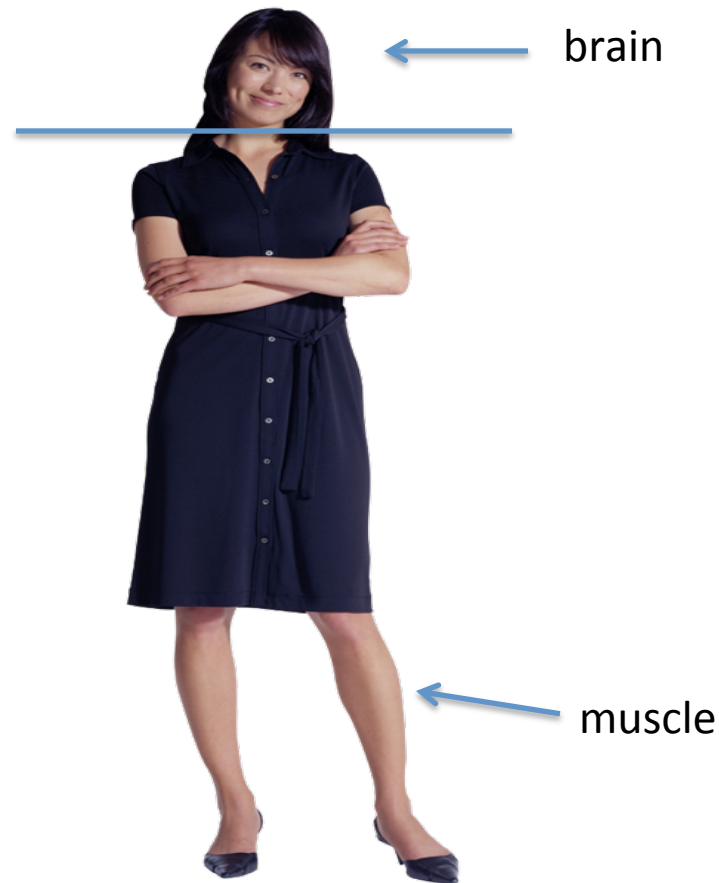


Exercise & the brain

Bernard (Bob) Gutin, PhD

Emeritus professor
Teachers College, Columbia University
&
Medical College of Georgia

Is there an interaction between what is above & below the line?



General outline of session

- Acute effects of single bouts of exercise

General outline of session

- Acute effects of single bouts of exercise
- Chronic effects of repeated bouts of exercise

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- Acute effects of single bouts of exercise
- Chronic effects of repeated bouts of exercise
- Relation of exercise & fitness to mental health

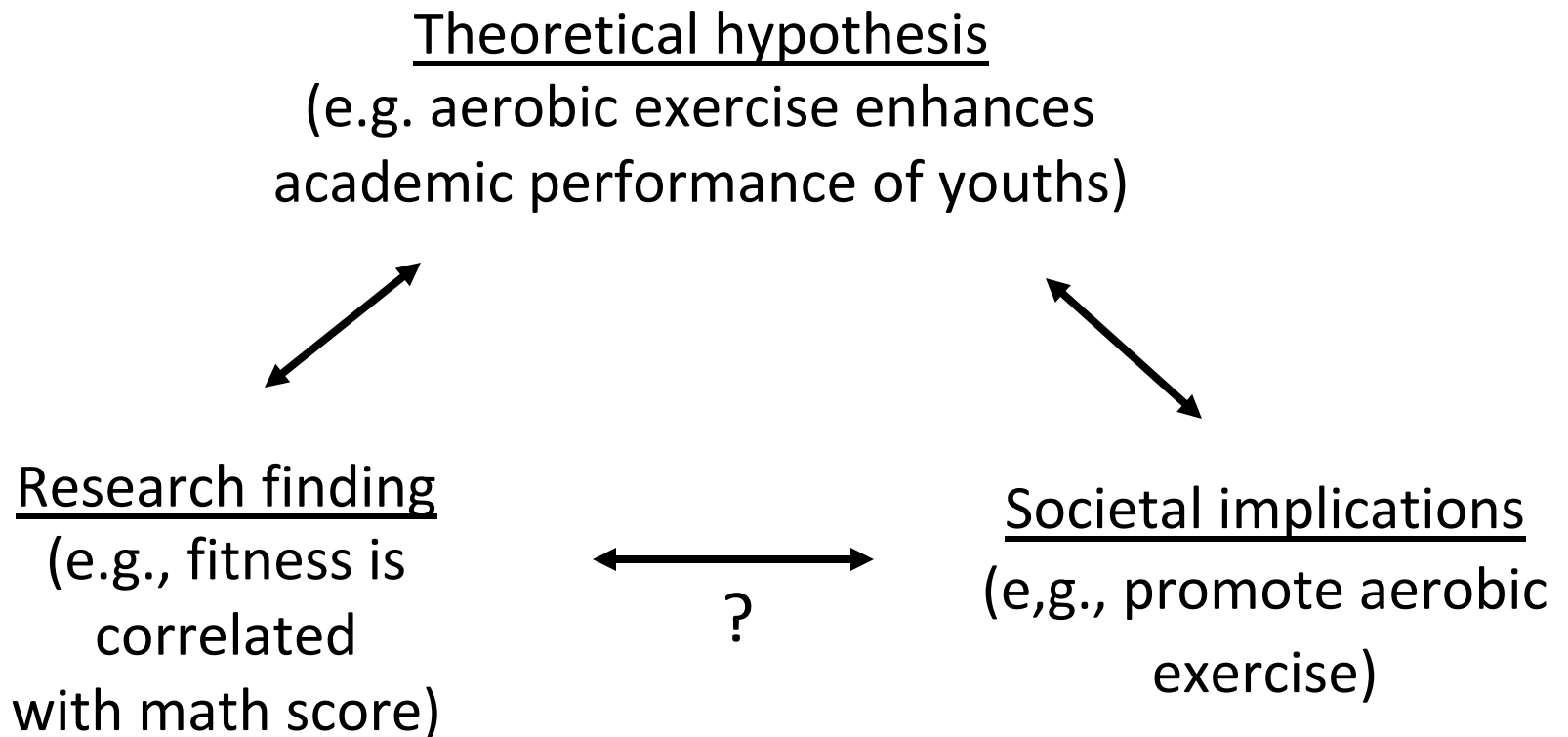
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- Effects of physical training on brain structure/
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General outline of session

- Acute effects of single bouts of exercise
- Chronic effects of repeated bouts of exercise
- Relation of exercise & fitness to mental health
- Effects of physical training on brain structure/function
- Traumatic effects of some sports on brain structure & function

How do we use research to cast light on personal behavior & public health practices?



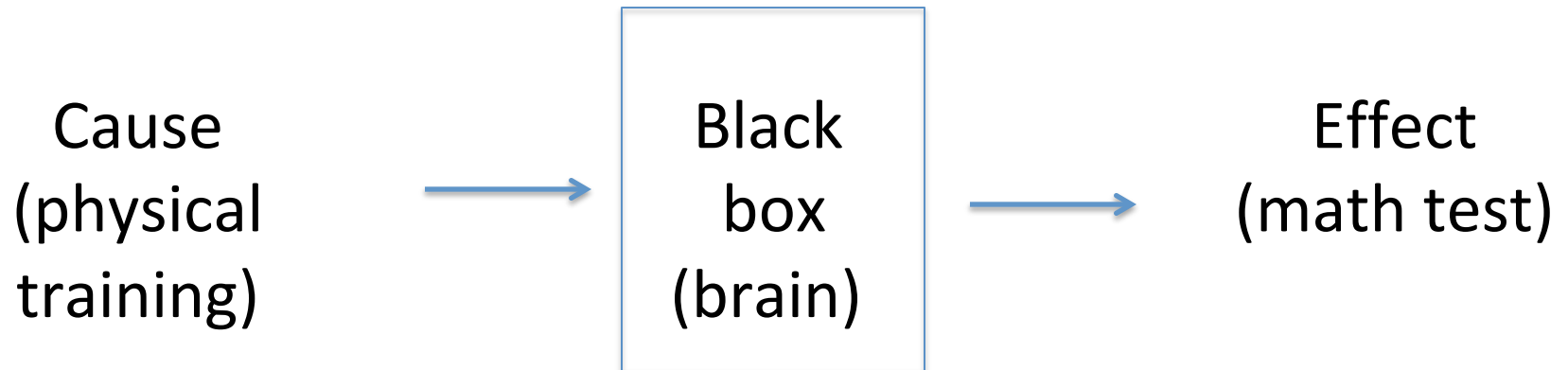
General model for assessing relationships

Cause
(e.g.,
physical
training)

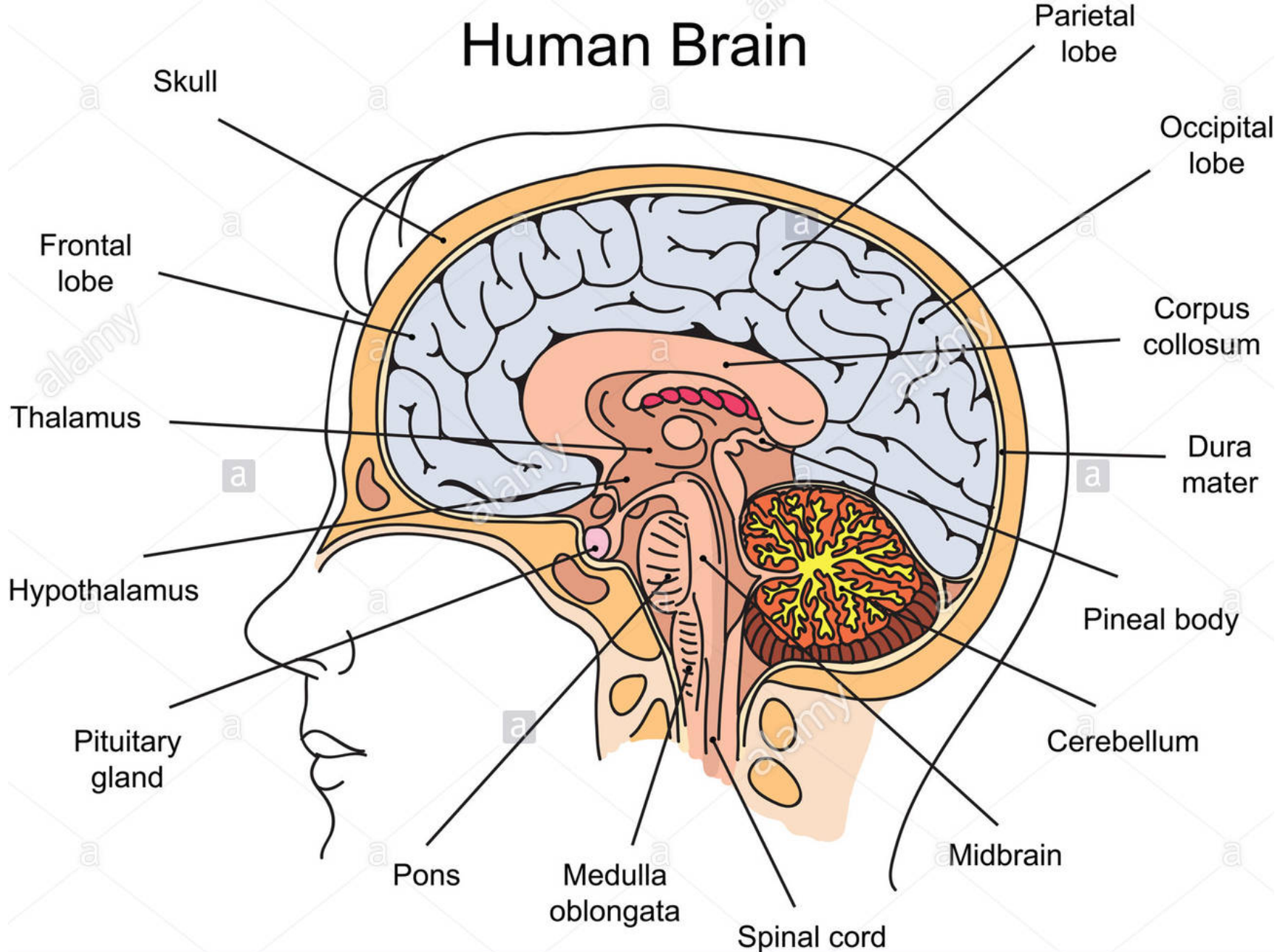


Effect
(e.g.,
math test)

What accounts for the relationships?



Human Brain



Potential mechanisms for acute or chronic effect of exercise on brain

- Increase brain blood flow

Potential mechanisms for acute or chronic effect of exercise on brain

- Increase brain blood flow
- Modulate general arousal level

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Potential mechanisms for acute or chronic effect of exercise on brain

- Increase brain blood flow
- Modulate general arousal level
- Delay age-related cognitive decline
- Enhance brain plasticity
- Up-regulate molecules related to brain activity
- Influence systemic inflammation

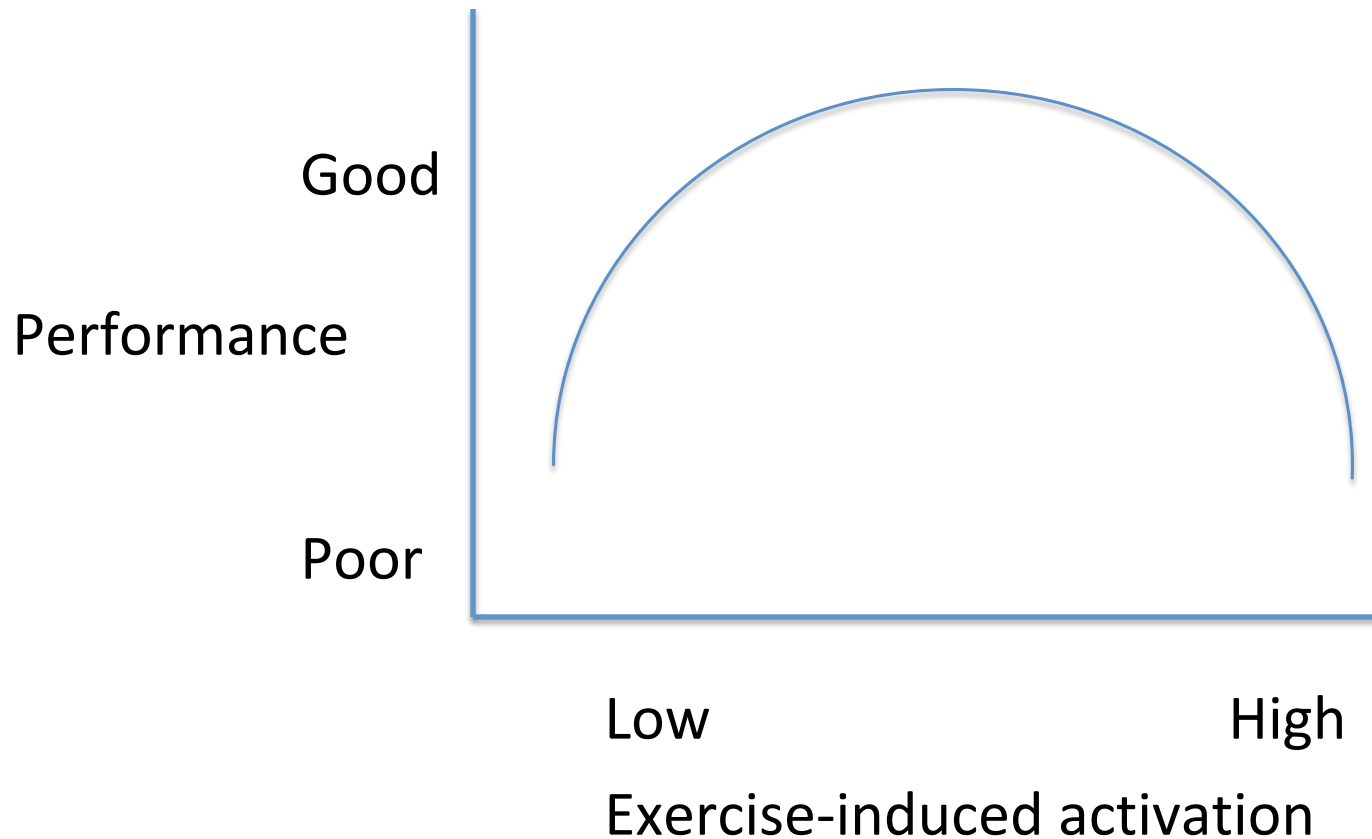
Effects of single bouts of exercise (1960's & 70's at CUNY & Columbia U.)

- Effects of warm-up on performance
 - Application to sports (e.g., wrestling practice)
 - Application to cognitive performance

Effects of single bouts of exercise (1960's & 70's at CUNY & Columbia U.)

- Effects of warm-up on performance
 - Application to sports (e.g., wrestling practice)
 - Application to cognitive performance
- Various tasks
 - Running or cycling
 - Repeated addition & subtraction
 - Choice reaction time
 - Movement speed
 - Hand steadiness

The inverted U-shaped relationship between activation & performance



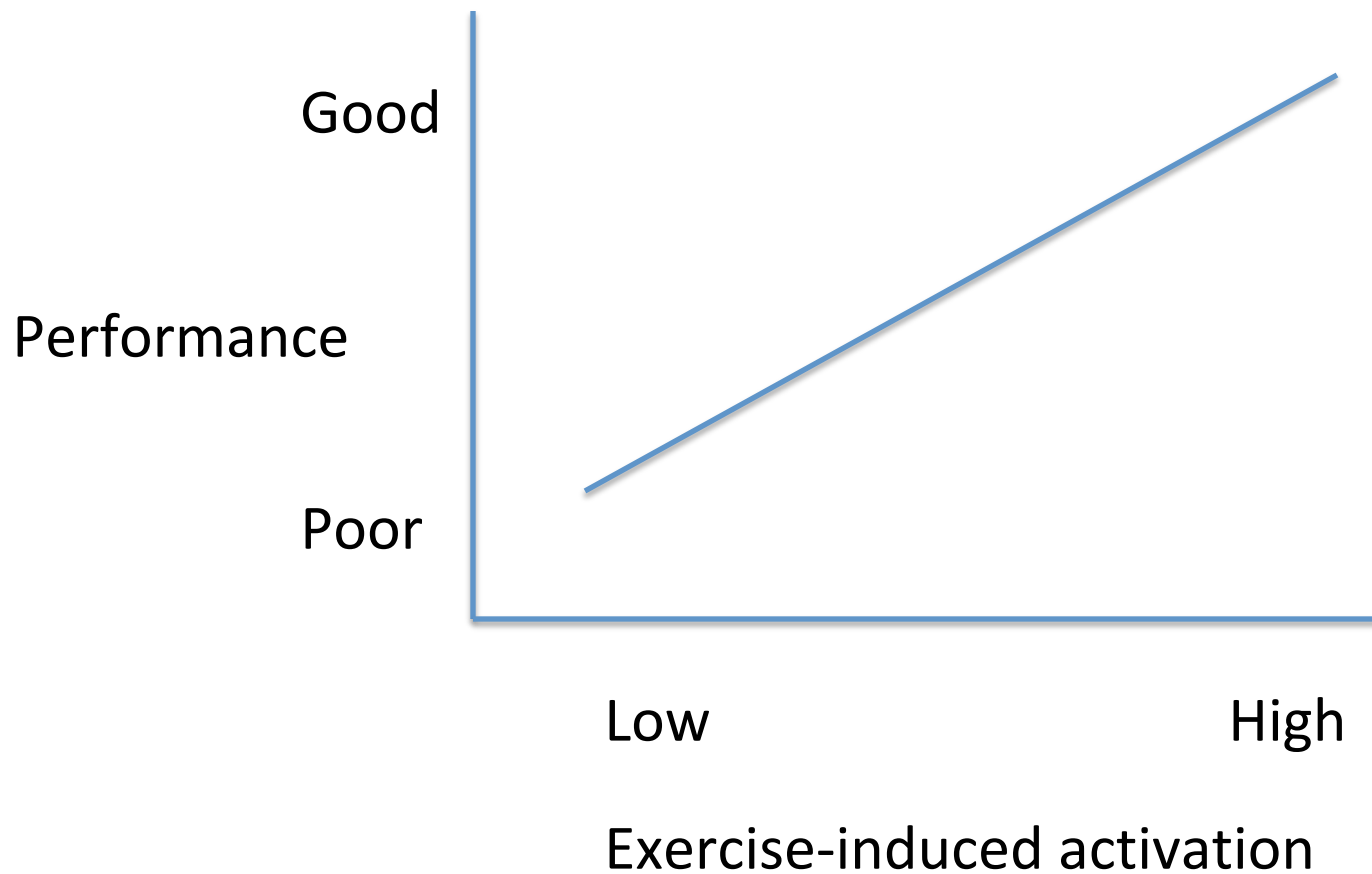
Is the “sweet spot” the same for all kinds of tasks?

For tasks involving precision (inhibition), a low EIA is optimal



Can you think of examples?

For tasks involving disinhibition, a high level of activation is optimal



Can you think of some examples?

Fast-forward to ~year 2000

- Catherine Davis, Phil Tomporowski in Georgia
- Kerry Stewart at Johns Hopkins
- Kramer & Hillman at Illinois
- Sophisticated measurements of cognition
- Brain-imaging studies

Exercise & brain function in children

(Davis, 2011)

- Subjects: 171 overweight 7-11 yr olds

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- Executive function: (select, organize, & initiate goal-directed actions)

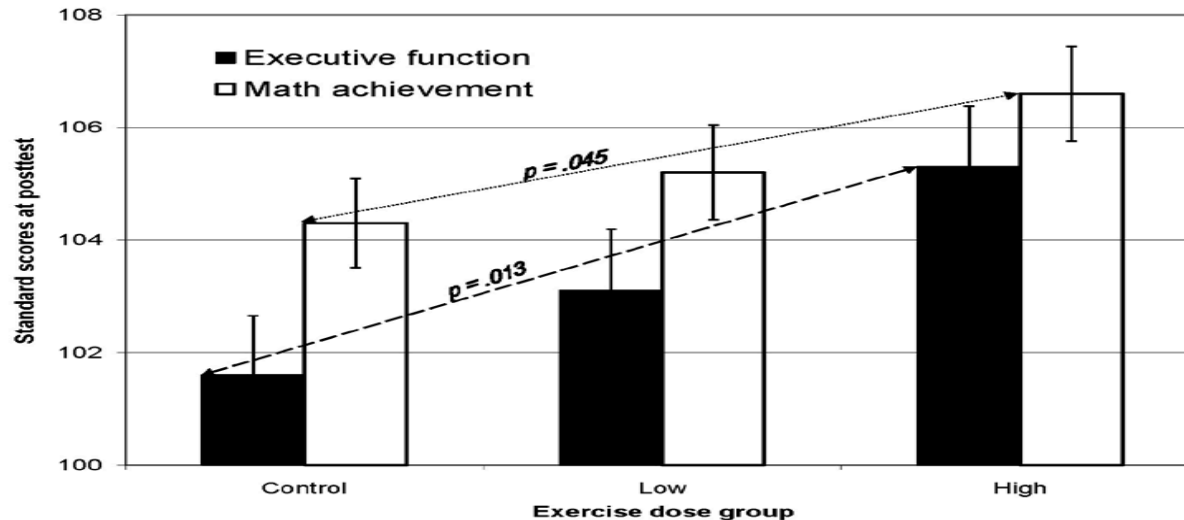
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- Executive function: (select, organize, & initiate goal-directed actions)
- Sub-study of functional MRI: measures blood flow to regions of brain

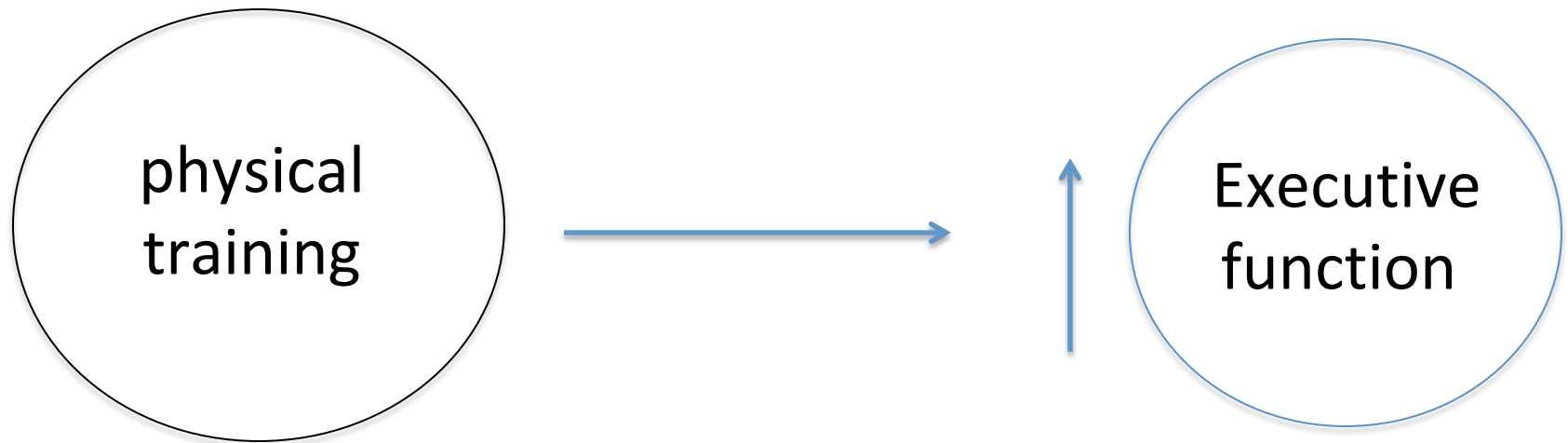
Effect of different doses of physical training on cognition in obese 7-11 yr olds

(Davis, 2011)



During the executive function test, prefrontal cortex activity was increased & posterior parietal cortex activity was reduced, indicating greater focus on the planning task

Cochrane Review of 18 studies, >2000 youths with obesity-overweight, 10 countries (Martin, 2018)



No significant effect for math, reading, inhibition control

What are executive functions?

- Processes in which there is a need to overcome habitual responses
 - Planning/decision-making
 - Inhibition control
 - Dangerous/technically difficult situations

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 - Planning/decision-making
 - Inhibition control
 - Dangerous/technically difficult situations
- Among the last mental functions to reach maturity; reach peak at age 20-29
- Best predictor of functional decline in the elderly

Physical activity & cognitive functioning of children: a systematic review (Biddzan-Bluma, 2018)

- 58 articles reviewed from 2000-2017

Exercise & cognition in pre-adolescence: a meta-analysis (de Greeff, 2018)

- Acute PA improves attention (EIA)
- Physical training improves executive functions & academic performance

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Stroop Task- executive function

- Test of cognitive flexibility, & response inhibition

Red Blue Green

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- In one condition, the words are color names that are either consistent or incompatible

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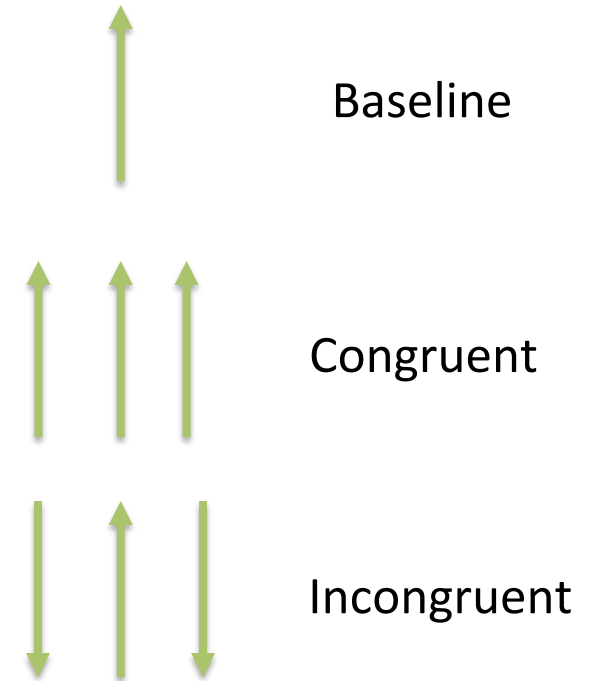
Stroop Task- executive function

- Test of cognitive flexibility, & response inhibition
- Subjects identify color of the word on the screen
- In one condition, the words are color names that are either consistent or incompatible
- In another condition the words are color neutral & subject asked to identify color

Red Blue Green
Red Blue Green
Red Blue Green

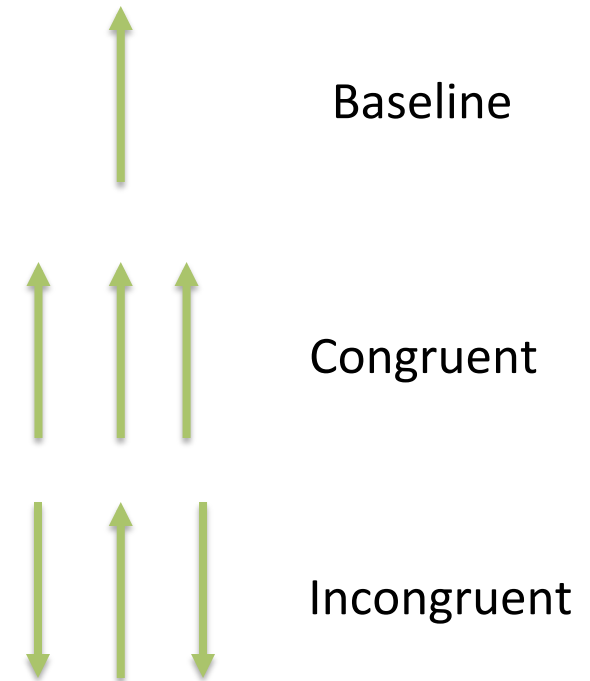
Eriksen Flanker Task (executive function)

- Fixate on a plus-sign in center of screen



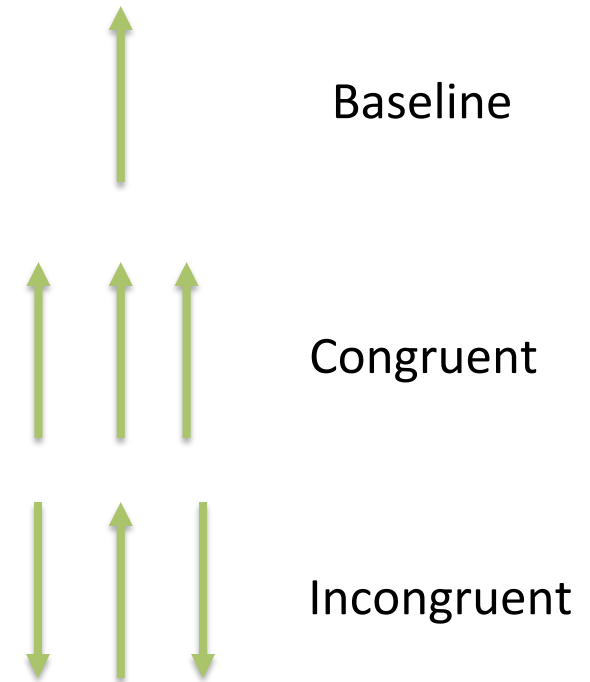
Eriksen Flanker Task (executive function)

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- An arrow pointing up or down appears & subjects identify direction



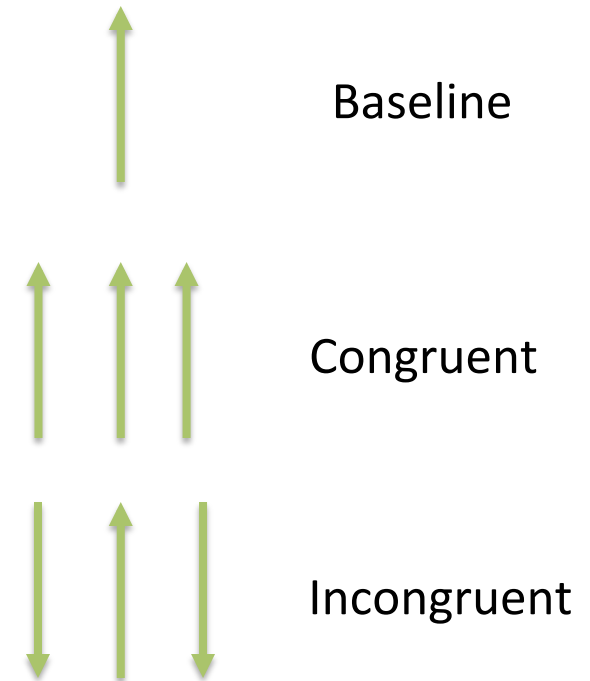
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Eriksen Flanker Task (executive function)

- Fixate on a plus-sign in center of screen
- An arrow pointing up or down appears & subjects identify direction
- Baseline condition, arrow appears alone
- In comparison condition, arrow is flanked by arrows pointing in the same or opposite direction of the center arrow



Mechanisms of exercise & the brain

(Ratey, *Spark*)

- Improves cardiovascular function
- Improves function of neurons
- Stimulates brain-derived neurotrophic factor (BDNF) in hippocampus, area related to memory & learning
- BDNF promotes neuronal growth (“Miracle-Gro” of the brain)

Exercise in a mouse model of Alzheimer's disease (AD) (Choi, 2018)

- Adult hippocampal neurogenesis (AHN) is impaired before the onset of AD pathology

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- Adult hippocampal neurogenesis (AHN) is impaired before the onset of AD pathology
- Exercise enhances AHN, levels of brain-derived neurotrophic factor (BDNF) & cognitive performance
- At early stages of AD, exercise & some pharmacological mimetics may protect against subsequent neuronal cell death

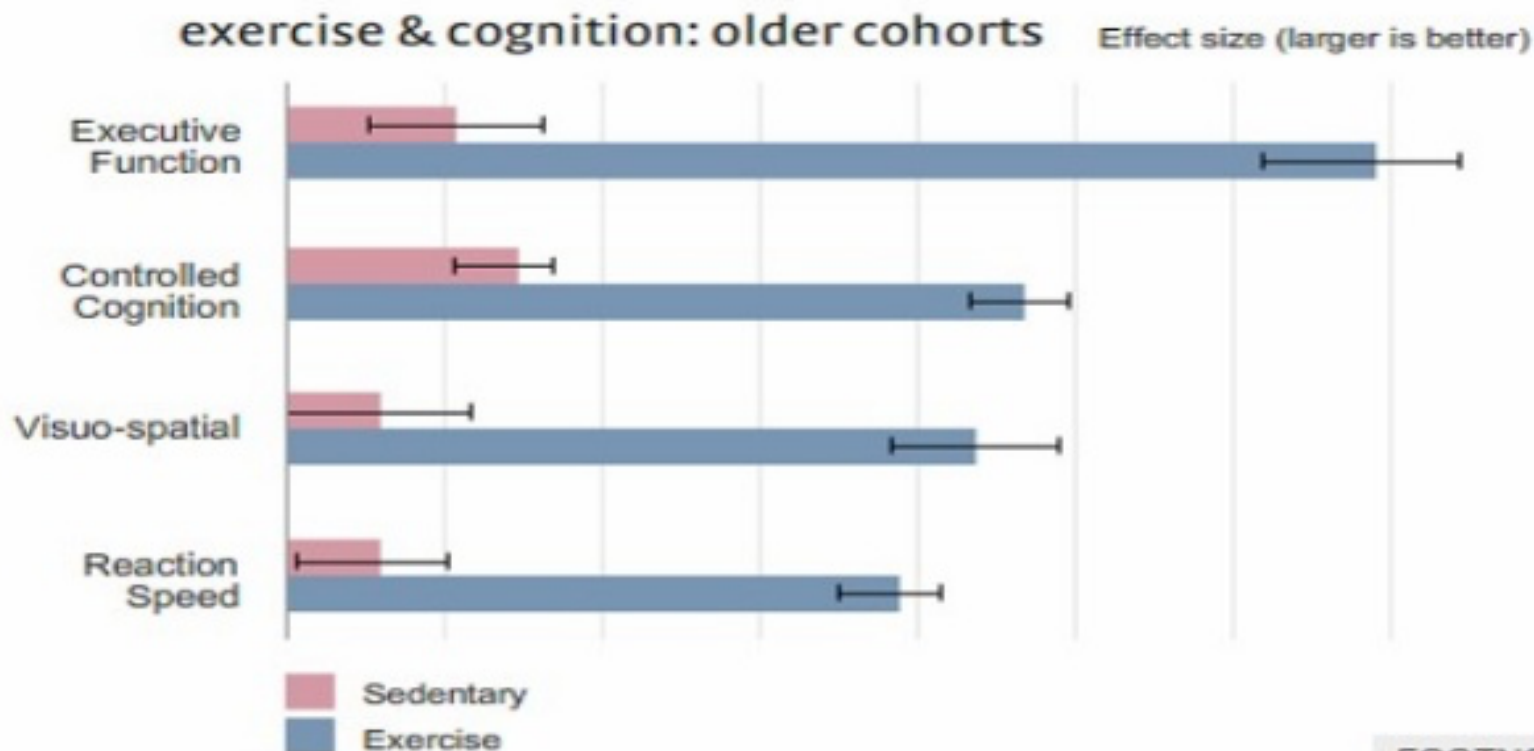
Leg power & cognitive ageing after
10 yr in older female twins, *Gerontology*,
2015

- Protective relationship between muscle fitness (leg power) & both 10-yr cognitive change & subsequent total grey matter

Leg power & cognitive ageing after
10 yr in older female twins, *Gerontology*,
2015

- Protective relationship between muscle fitness (leg power) & both 10-yr cognitive change & subsequent total grey matter
- Leg power predicts both cognitive ageing & global brain structure, despite controlling for common genetics & early life environment shared by twins



The cognitive value of exercise





FOOTNOTES

Source: Colcombe, S and Kramer, AF (2003)
Fitness effects on the cognitive function of older adults: a meta-analytic study
Psych Sci 14: 125 - 130

Exercise & cognition in aging (Gomes-Osman, 2018)

- Reviewed 98 RCTs
- Exercising for at least 52 hr   cognition
 - global, speed, & executive function most stable

Exercise & cognition in aging (Gomes-Osman, 2018)

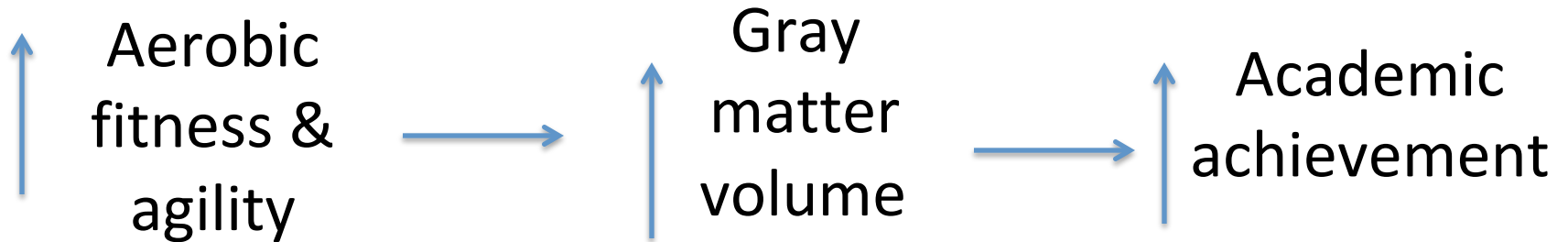
- Reviewed 98 RCTs
- Exercising for at least 52 hr   cognition
 - global, speed, & executive function most stable
- Effective exercise modes
 - aerobic
 - strength
 - mind-body
 - combinations

Whole brain volume

(Esteban-Cornejo, 2017)

- Obesity is associated with structural differences in brain
- Studied overweight Spanish youths (8-11 yr)
- Higher aerobic fitness & speed-agility (but not muscular fitness) associated with
 - Better academic performance
 - Greater gray matter volume in several brain regions

Hypothetical implication of Esteban-Cornejo results



Physical activity (PA) & cognition in adults at risk for Alzheimer disease (AD)

311 people with
memory problems
randomized to

- Usual care
- 24-wk home-based PA
program (150 min/wk)

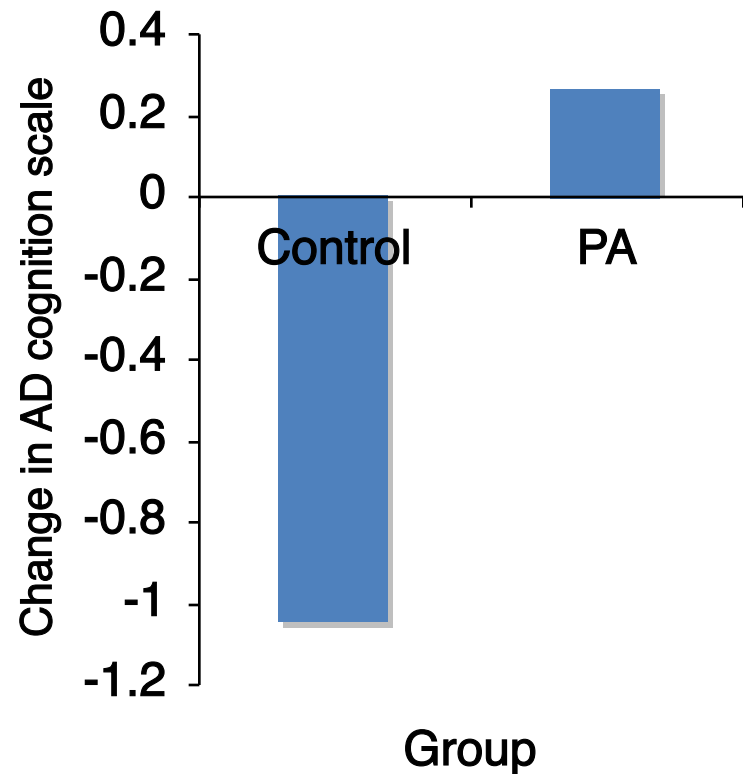
Main outcome - AD
cognitive scale

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Physical training (PT) & the hippocampus (Erickson, 2011)

- Aging leads to shrinkage of hippocampus, leading to impaired memory & risk for dementia
- Fitter people have larger hippocampi
- Exercise increases hippocampal perfusion

Effect of PT on aerobic fitness & hippocampus volume in adults (Erickson, 2011)

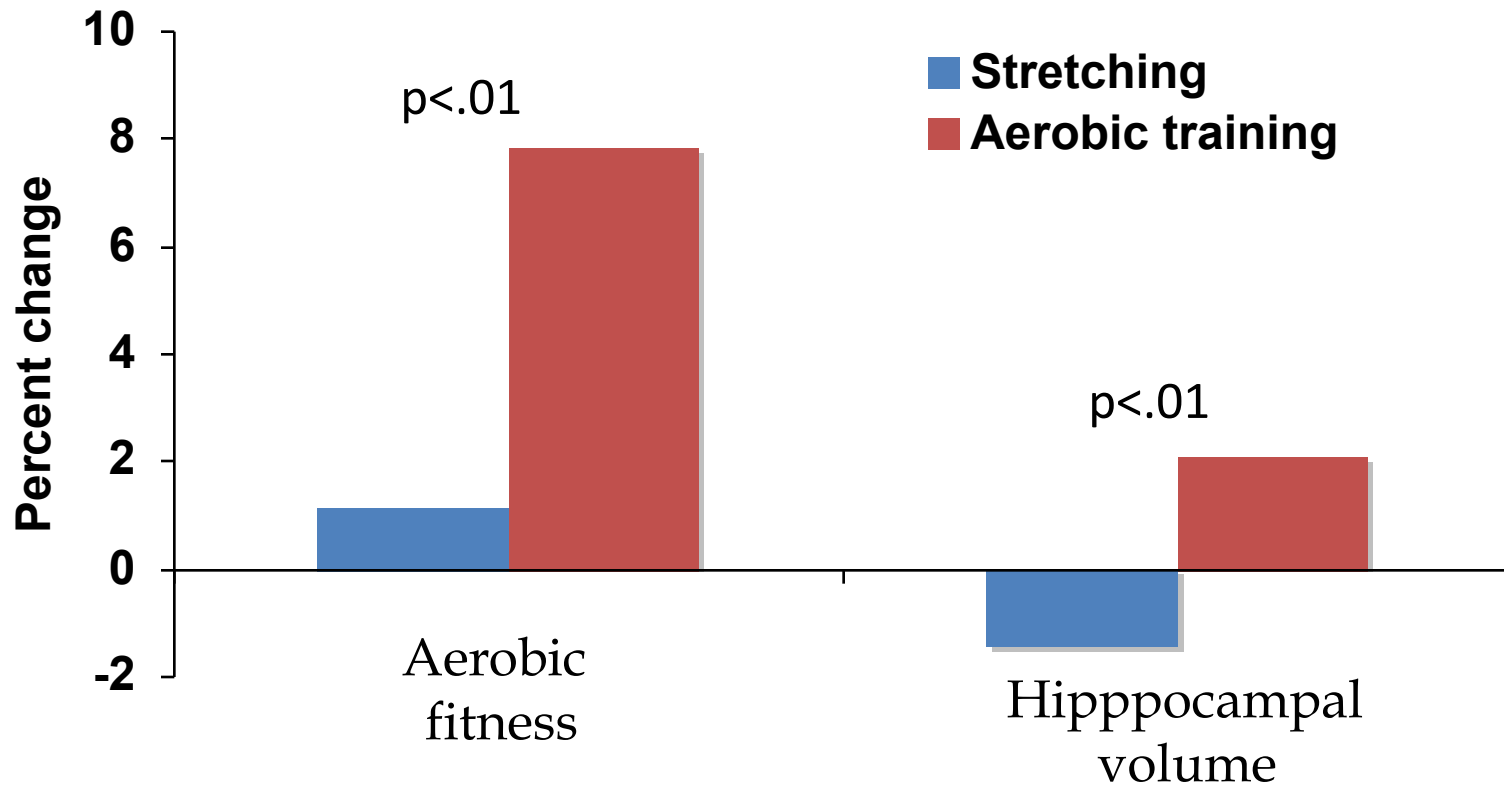
- 120 adults (mean age ~67)
- Randomly assigned to
 - Stretching
 - Aerobic training - 3 days/wk for 12 mo

Effect of PT on aerobic fitness & hippocampus volume in adults

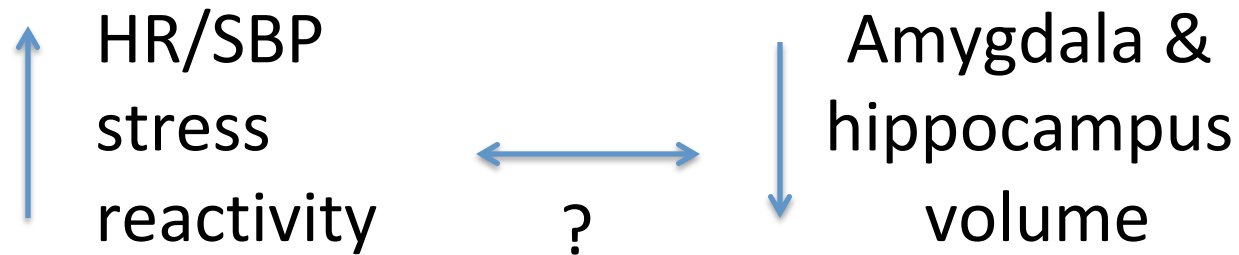
(Erickson, 2011)

- 120 adults (mean age ~67)
- Randomly assigned to
 - Stretching
 - Aerobic training - 3 days/wk for 12 mo
- Compared to the stretching group, the PT group increased in
 - Aerobic fitness
 - Hippocampal volume

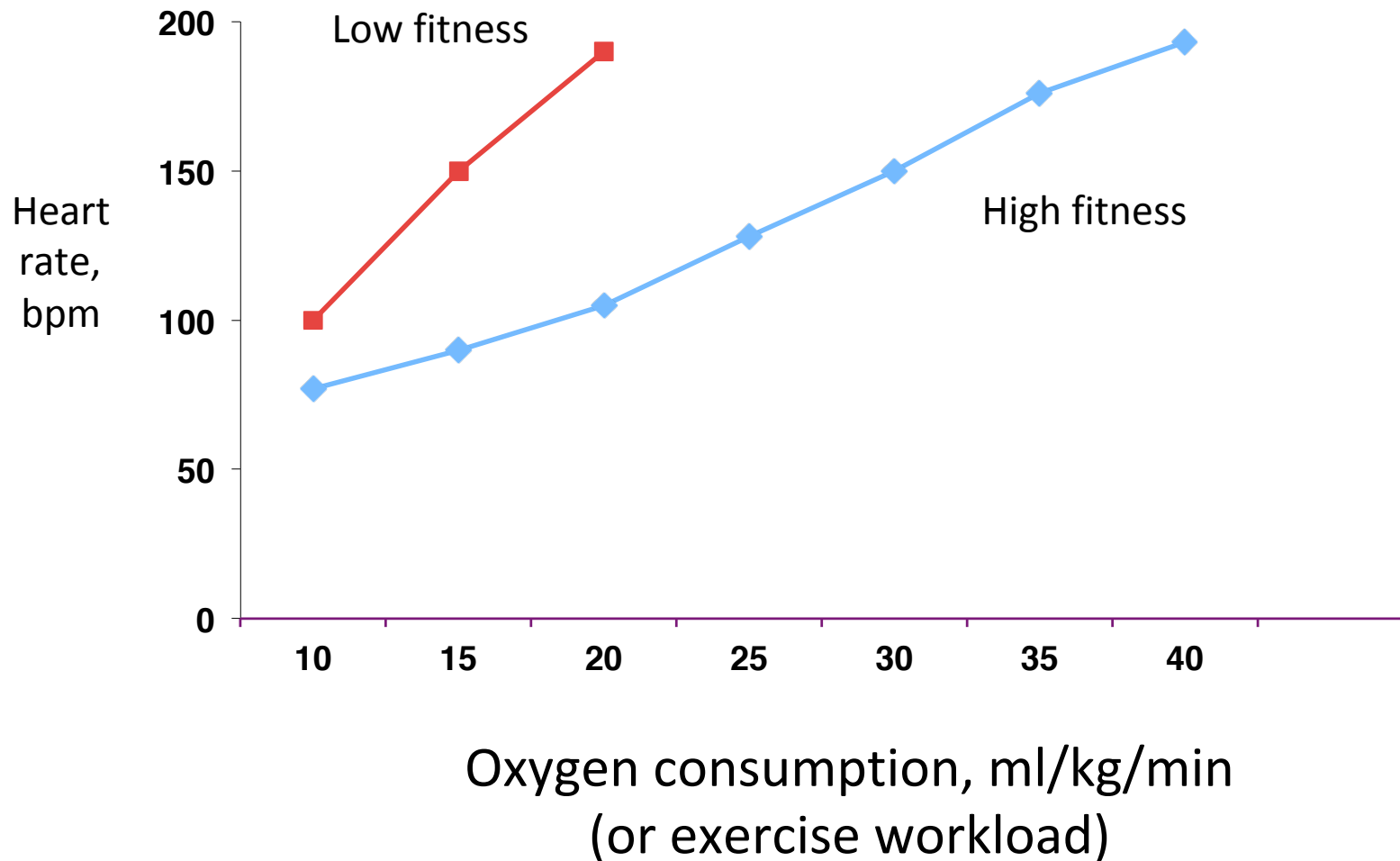
Changes in fitness & hippocampal volume following 1 yr of intervention



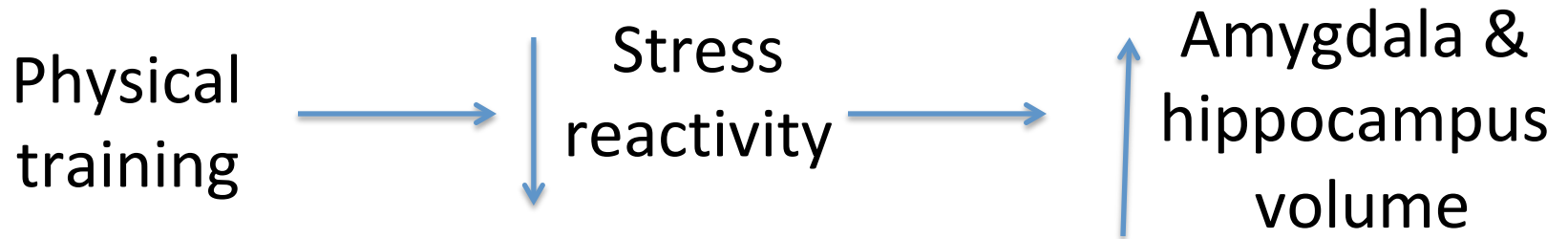
CV reactivity to stressors & brain volumes (Trotman, 2018)



Stress response to a variety of stressors is lower in people who are more fit



How might exercise play a role?



Yesterday's NY Times (Velasques-Manoff, 2018)

Infections  Mental disease

?

Thinking while moving or moving
while thinking? (Herold, 2018)

Incorporating cognitive tasks into
motor tasks is the most promising way
to enhance cognitive reserve

Walk-station



Aging brain: effect of combined cognitive & physical training (CCPT) compared to each alone – a review (Joubert, 2018)

- CCPT > either alone

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- CCPT > either alone
- Good long-term maintenance (4-5 yr)

Aging brain: effect of combined cognitive & physical training (CCPT) compared to each alone – a review (Joubert, 2018)

- CCPT > either alone
- Good long-term maintenance (4-5 yr)
- Physical & cognitive training play different but complementary roles in brain plasticity

Acute & chronic effect of exercise on cognition in young people with ADHD: A review of intervention studies (Suarez-Manzano, 2018)

- 20-30 min of moderate-intensity exercise acutely enhances processing speed, working memory, problem solving

Acute & chronic effect of exercise on cognition in young people with ADHD: A review of intervention studies (Suarez-Manzano, 2018)

- 20-30 min of moderate-intensity exercise acutely enhances processing speed, working memory, problem solving
- Moderate-intensity PT (>30 min/d, >5 wk) improves attention, inhibition, emotional control, behavior, & motor control

Slow-Wave Activity Enhancement to Improve Cognition (Wilckens, 2018)

- Slow-wave activity (SWA), & its coupling with other sleep features, reorganizes cortical circuitry, supporting cognition

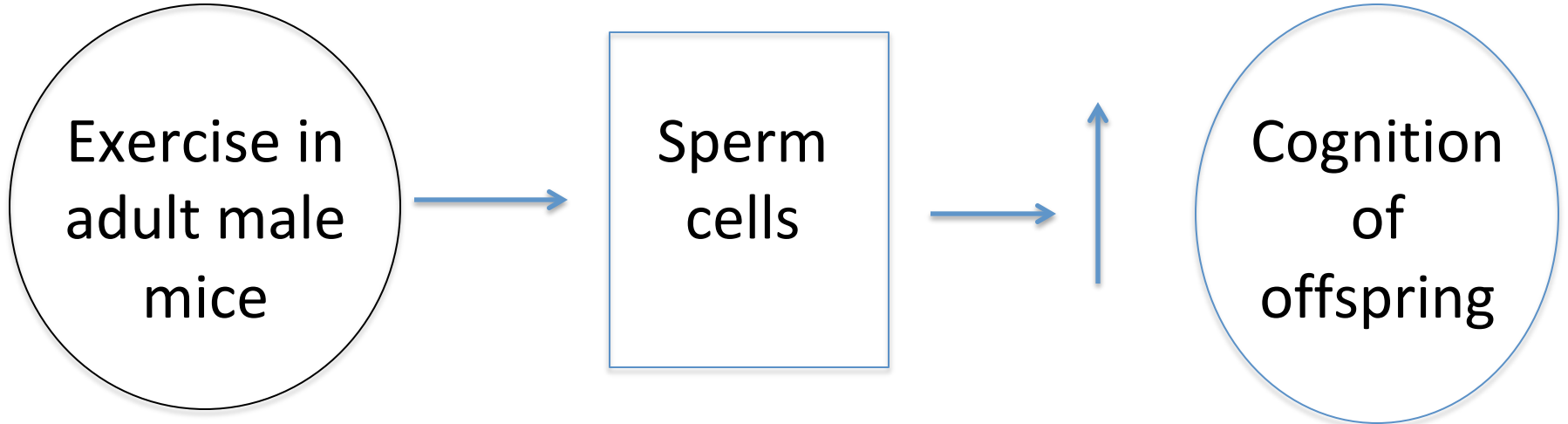
Slow-Wave Activity Enhancement to Improve Cognition (Wilckens, 2018)

- Slow-wave activity (SWA), & its coupling with other sleep features, reorganizes cortical circuitry, supporting cognition
- Exercise (also meditation & sexual activity) enhances SWA sleep, improving
 - executive function
 - learning
 - memory

Interventional programs to improve cognition during healthy & pathological ageing: evidence for brain plasticity (Cespon, 2018)

Multi-modal programs are better than programs using a single interventional approach in healthy elderly & cognitively impaired subjects, including patients with mild cognitive impairment & Alzheimer's disease

Is there an epigenetic effect of exercise? (Benito, 2018)



Sarcopenic obesity & cognitive performance (Tolea, 2018)

- Studied 353 participants, average age of 69 yr

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- Sarcopenia (low muscle mass) negatively influences cognition
- Sarcopenic effect is especially strong when combined with obesity
- At-risk older adults may benefit from programs that maintain or improve strength & prevent obesity

Obesity & onset of depressive symptoms among middle-aged and older adults in China (Luo 2018)

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- Obese males (but not females) were less likely to become depressed
- Males judge a smaller body frame as less desirable than a larger, more muscular body

Physical activity & incident depression:
meta-analysis of 49 prospective cohort
studies; N=266,939 (Schuch, 2018)

Physical activity can confer protection against the
emergence of depression regardless of age &
geographical region



PHYSICAL EXERCISE IS THE KEY TO BRAIN HEALTH

 DEVELOPINGHUMANBRAIN.ORG

RESOURCES:

<http://www.health.harvard.edu/blog/regular-exercise-changes-brain-improve-memory-thinking-skills-201404097110>
<http://thebrainflux.com/brain-benefits-of-exercise/>

Unknowns

- Optimal doses/types of exercise for different tasks
- Optimal combinations of exercise & CNS activity for long-term learning
- Specific regions of brain & specific cognitive functions involved
- Carryover to normal life functions



Exercise Your Brain

Are there any downsides to
exercise for the brain?

Longitudinal changes in linguistic complexity in professional football players (Berisha, 2017)

- Reductions in linguistic complexity associated with onset of neurological disorders
- Studied interviews over 8-yr period
- It declined more in players than in executives who have not played football
- For quarterbacks, it declined in proportion to the average number of times they were sacked/game

Chronic traumatic encephalopathy (CTE)

- Neurodegenerative disease, leads to aggression & dementia

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- Found in 110/111 (90%) of brains of former football players who had shown signs of pathology (Mez, 2017)

Chronic traumatic encephalopathy (CTE)

- Neurodegenerative disease, leads to aggression & dementia
- Found in 110/111 (90%) of brains of former football players who had shown signs of pathology (Mez, 2017)
- Should football (& other sports involving potential brain damage) be sponsored by parents & public agencies?

Systematic review of mild traumatic brain injury in youths (Emery, 2016)

Few rigorous prospective studies have shown that psychological, behavioral and/or psychiatric problems persist beyond the short-term phase following mild traumatic brain injury

Summary of exercise & brain function

- Exercise influences brain activation to have positive or negative effects on performance & learning

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- Physical training improves fitness, circulation, brain metabolism, resistance to stressors, size of brain regions

Summary of exercise & brain function

- Exercise influences brain activation to have positive or negative effects on performance & learning
- Physical training improves fitness, circulation, brain metabolism, resistance to stressors, size of brain regions
- Combining optimal exercise intensity with CNS activity enhances performance & learning

General conclusions

- Like the rest of the body, the brain responds to stress
 - Favorably to optimal doses
 - Unfavorably to insufficient or excessive doses
- The brain can also be kept in shape by brain fitness exercises
- Sounds like OLLI at Duke should be prescribed to all!



organismic interaction

Quotation on wall at
Columbia U. when I
joined the faculty in 1968

“A day of high moral purpose
depends on one’s circulation
as well as one’s logical grounds.”

Jesse Feiring Williams

- Thank you for your attention
- Slides will be uploaded to the course website:
olliatdukefrontiersinmedicine.weebly.com

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- If you have a question or comment, please stand (if you can) & speak into the microphone