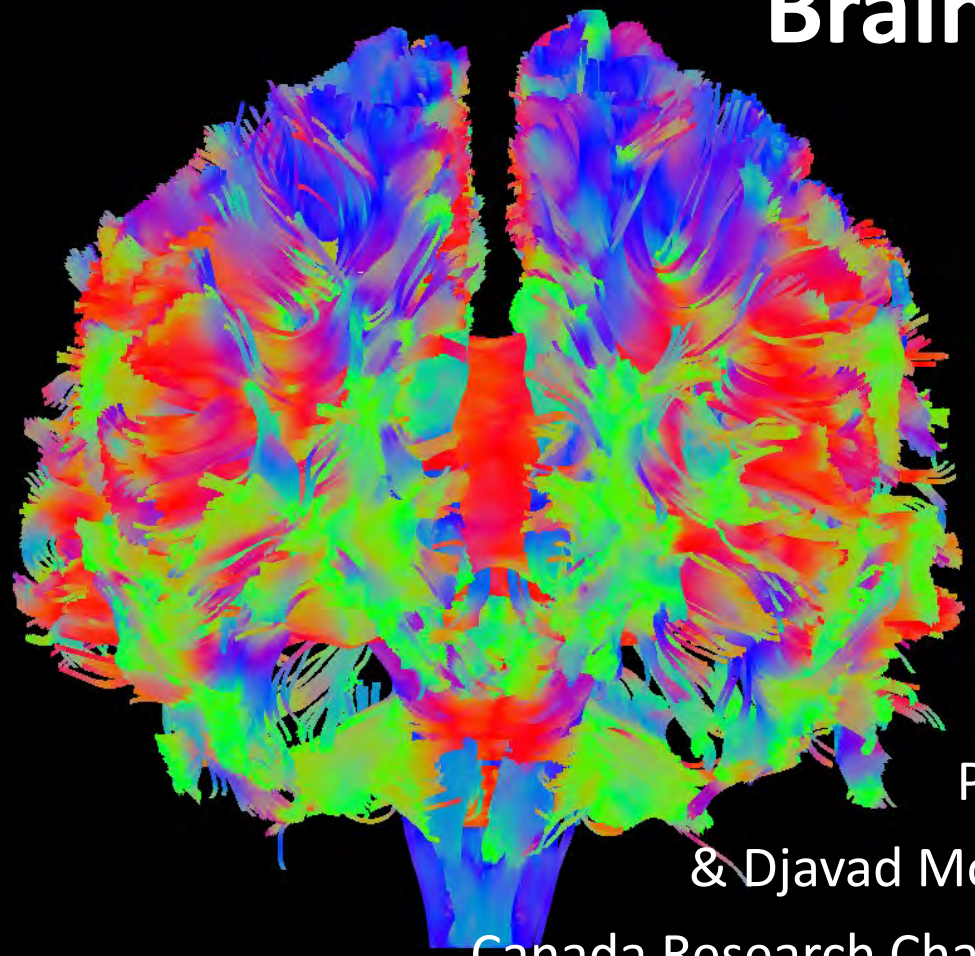
Learning and Development Across the Lifespan: Healthy Bodies, Healthy Brains



Lara Boyd, PT, PhD

Professor, Dept. of Physical Therapy

& Djavad Mowafaghian Centre for Brain Health

Canada Research Chair, Neurobiology of Motor Learning

lara.boyd@ubc.ca

I. The Learning and Neuroplastic Brain

II. Neuroplasticity: Promise and Peril

III. Exploiting Neuroplasticity

Part I. The Learning and Neuroplastic Brain

Neuroplasticity

- All learning of new facts and skills as well as re-learning to support recovery from brain damage is represented neurologically by plasticity or structural change in the brain

- Both mature and developing brains are constantly reorganizing

- You are doing it right now

Neuroplasticity

- Brain plasticity supports all learning
- Brain plasticity after neurological insults contributes to recovery
- Specific interventions can facilitate positive plasticity throughout life

Neuroplasticity is Experience-Dependent

- The adaptive capacity of the brain is highly influenced by behaviour
  - There is no drug that promotes neuroplasticity
  - Neuroplastic patterns can be highly variable from person to person
- Neuroplasticity can be both **positive** (learning) and **negative** (addiction)

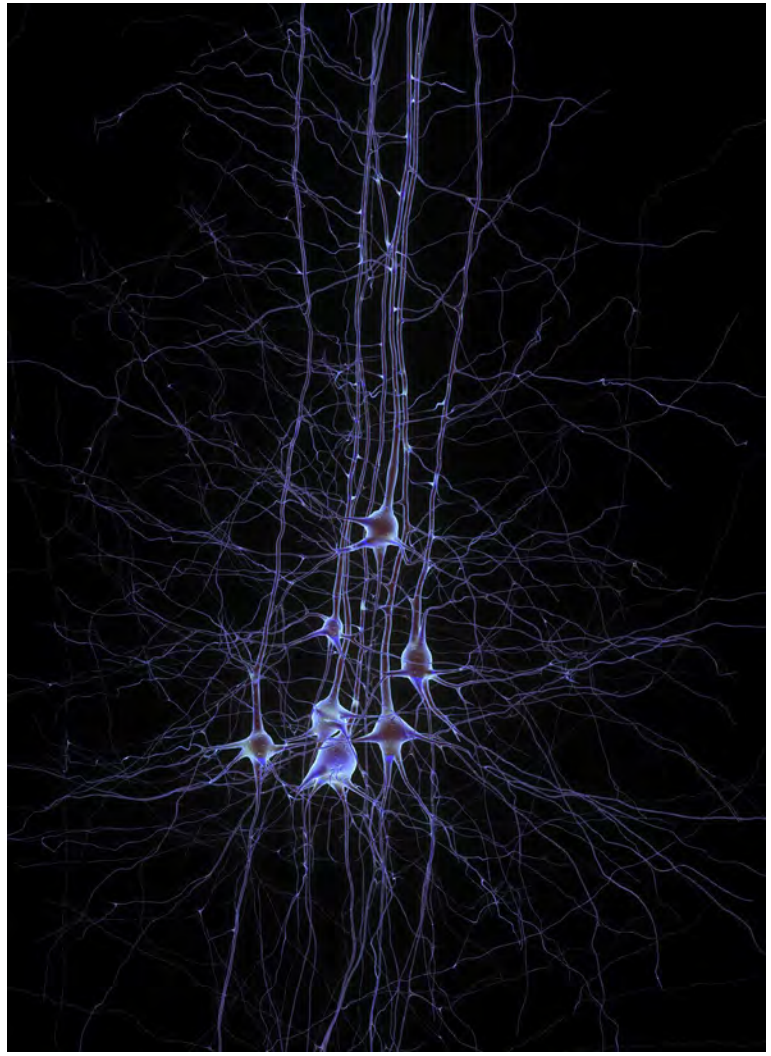
➢What limits and what facilitates neuroplasticity?

Neuroplastic Change

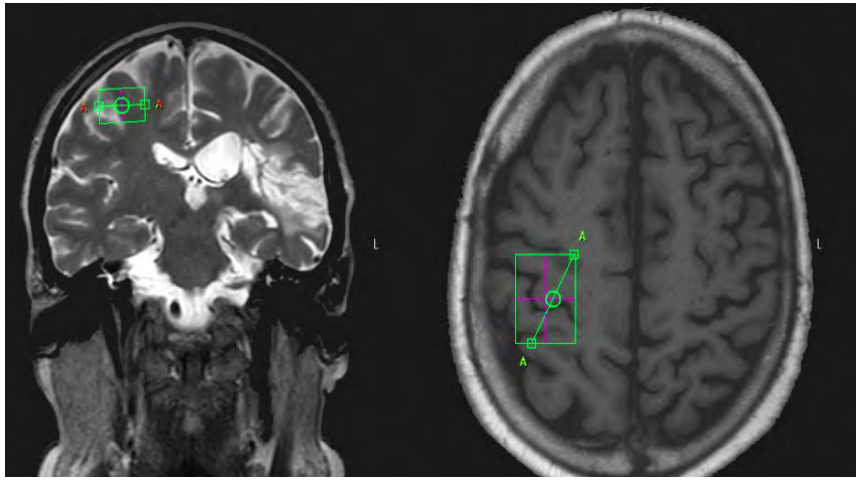
Neuroplasticity is driven by change in:

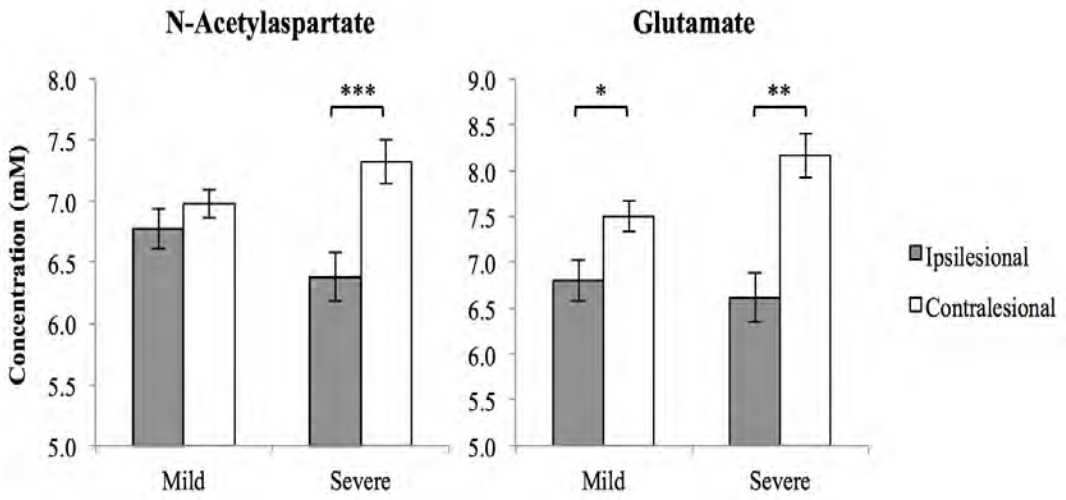
1. Brain Chemistry
2. Brain structure
3. Brain Function
4. All of the above

Brain Chemistry



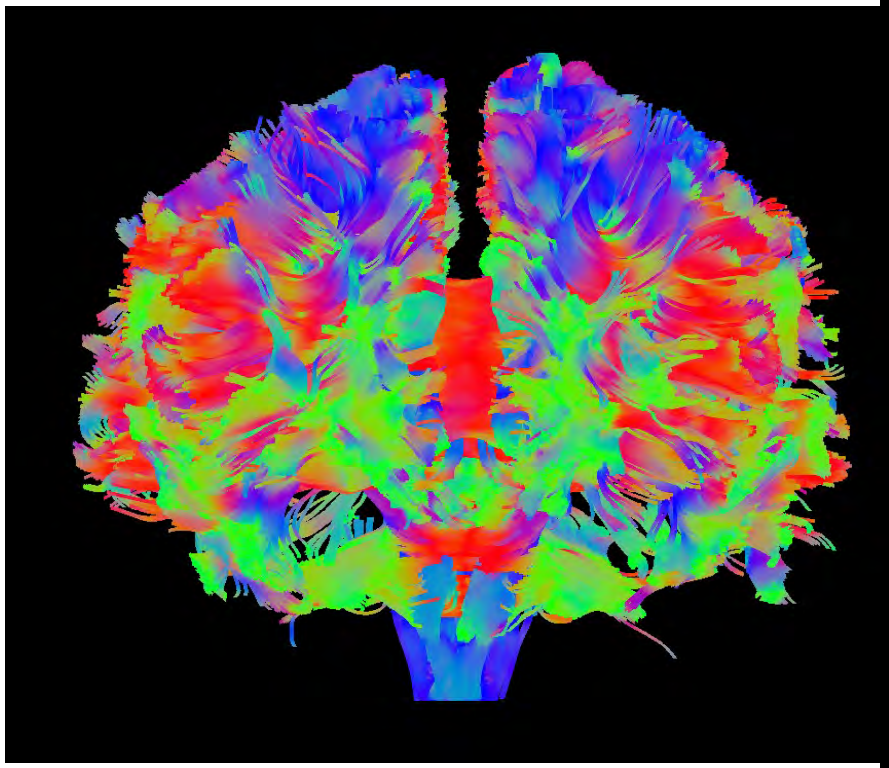
adapted from Kandel, 2013

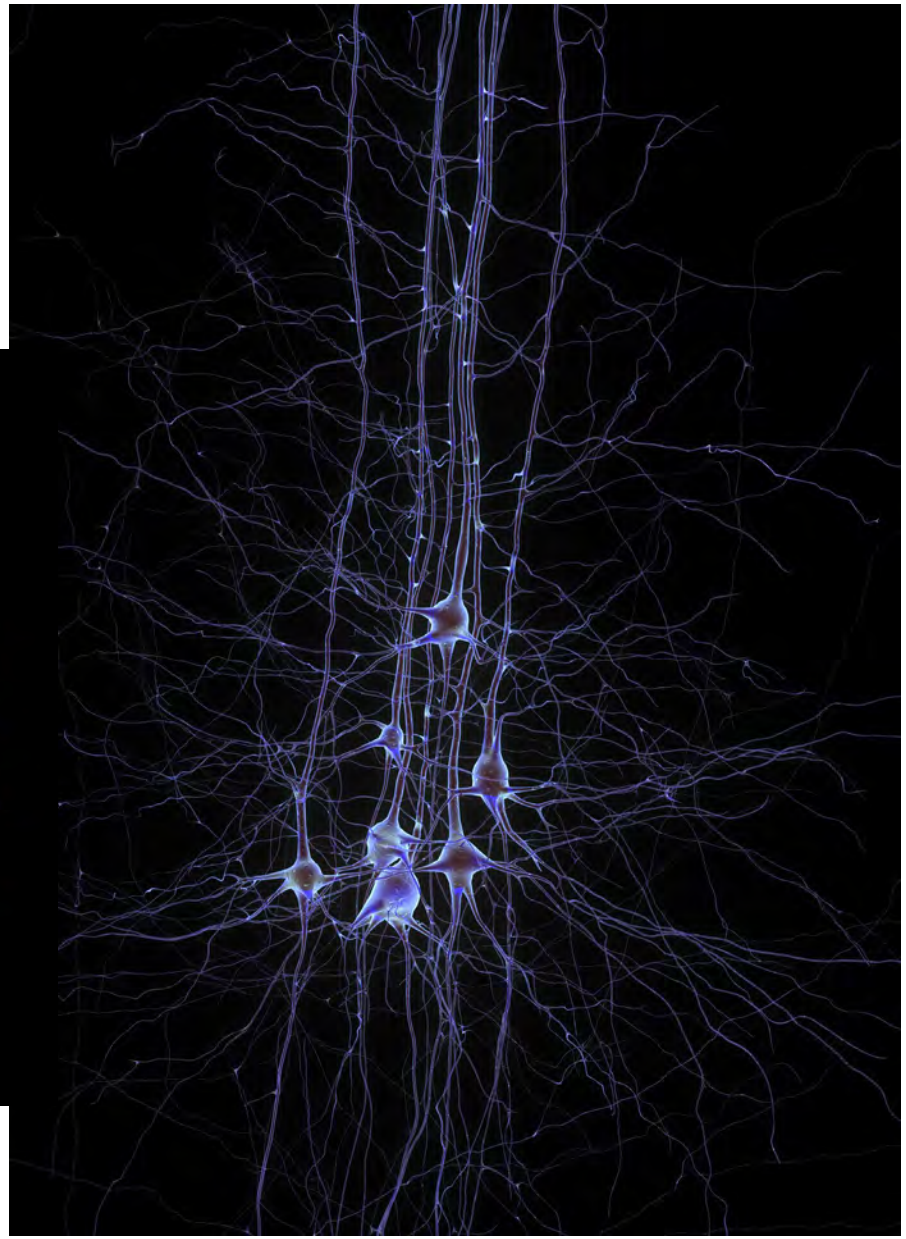




Ferris et al, 2016

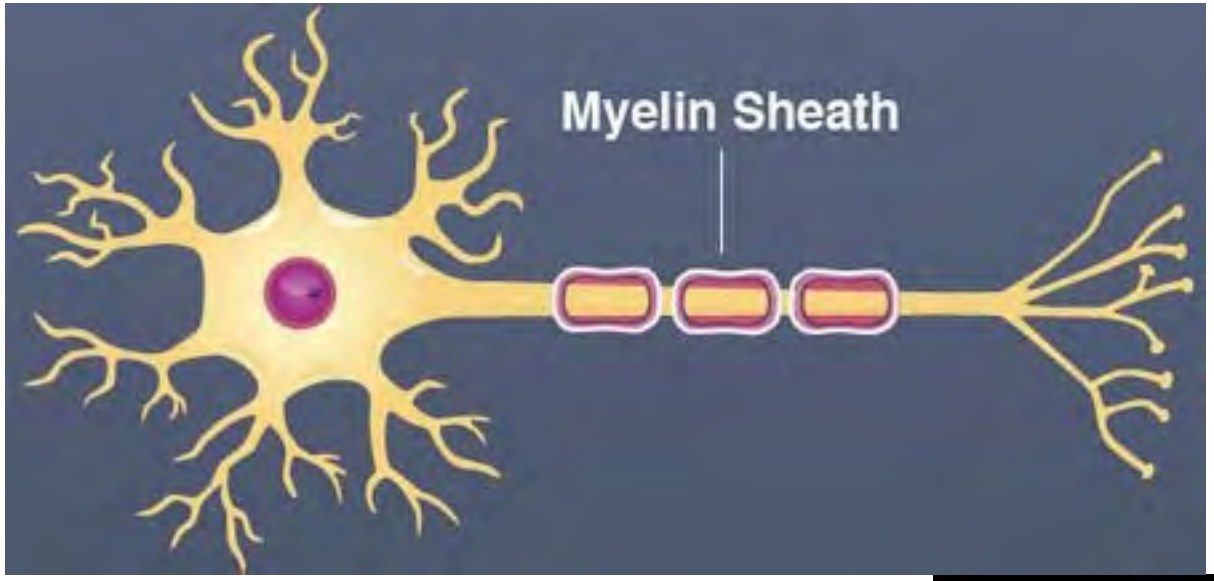
Brain Structure





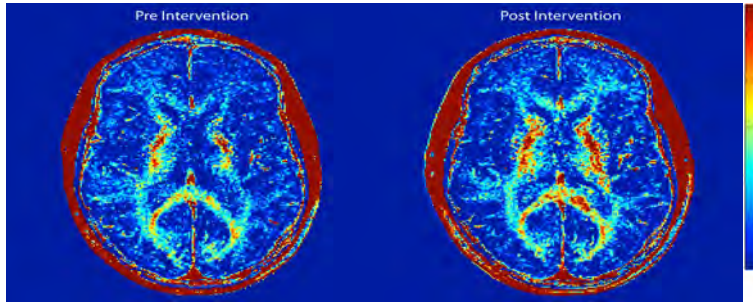
adapted from Kandel, 2013

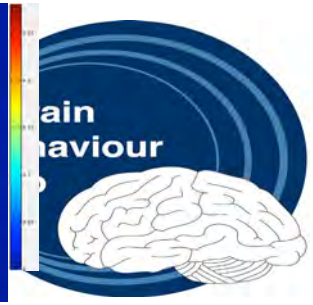
Myelin

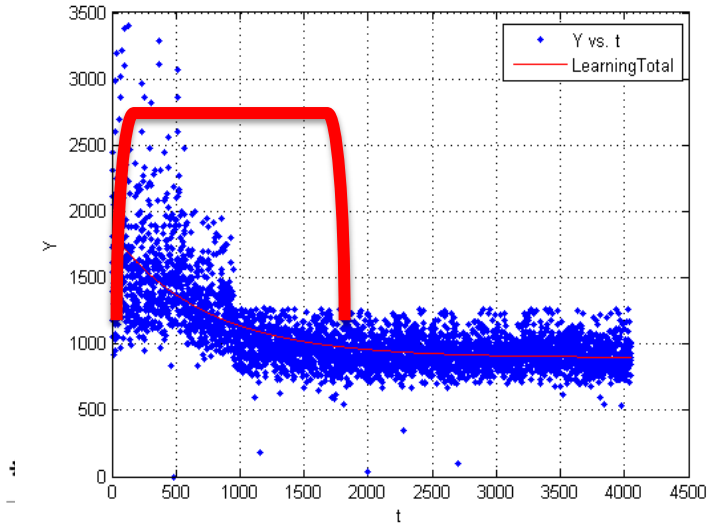

Myelin Sheath

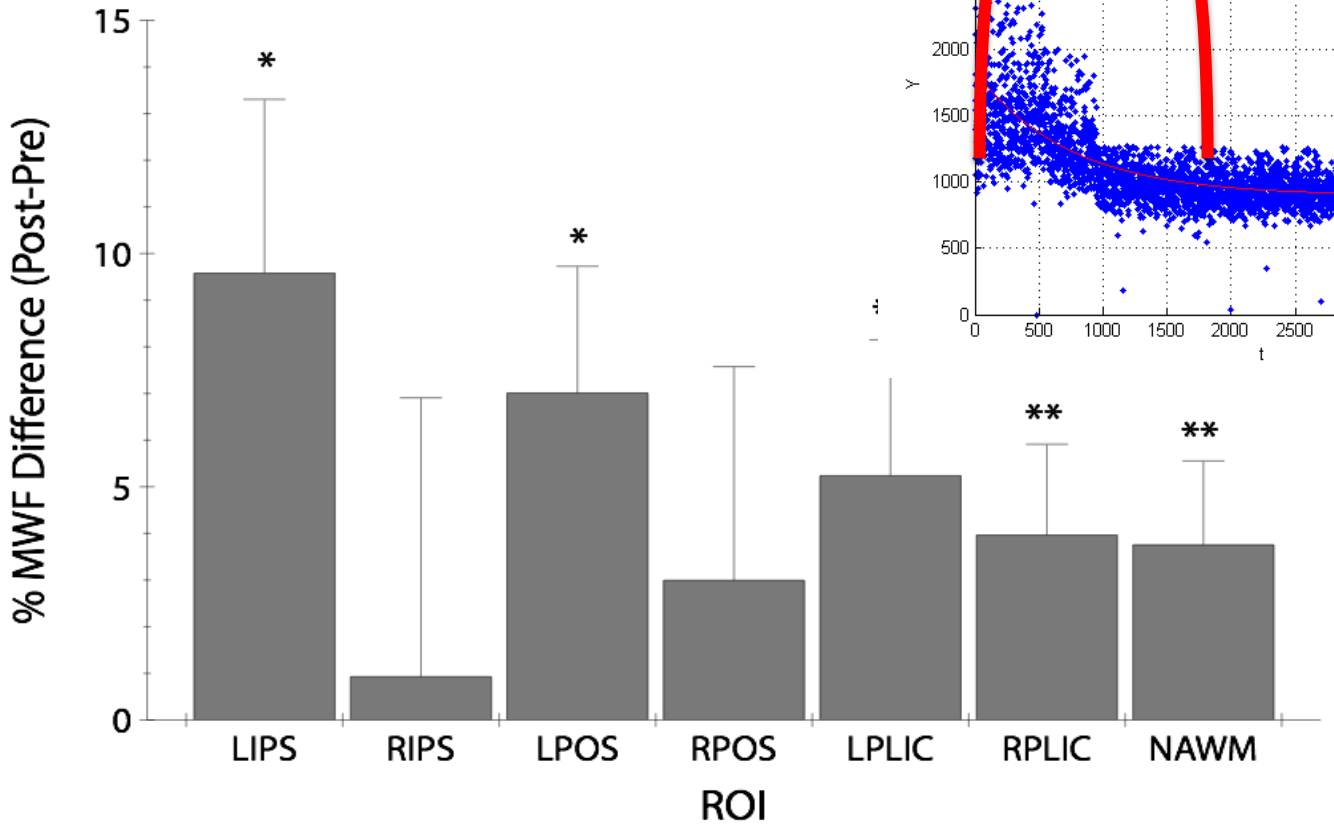

© Photo Quest Ltd/Science Photo Library/Corbis

Learning Increases Myelin in the Healthy Human Brain









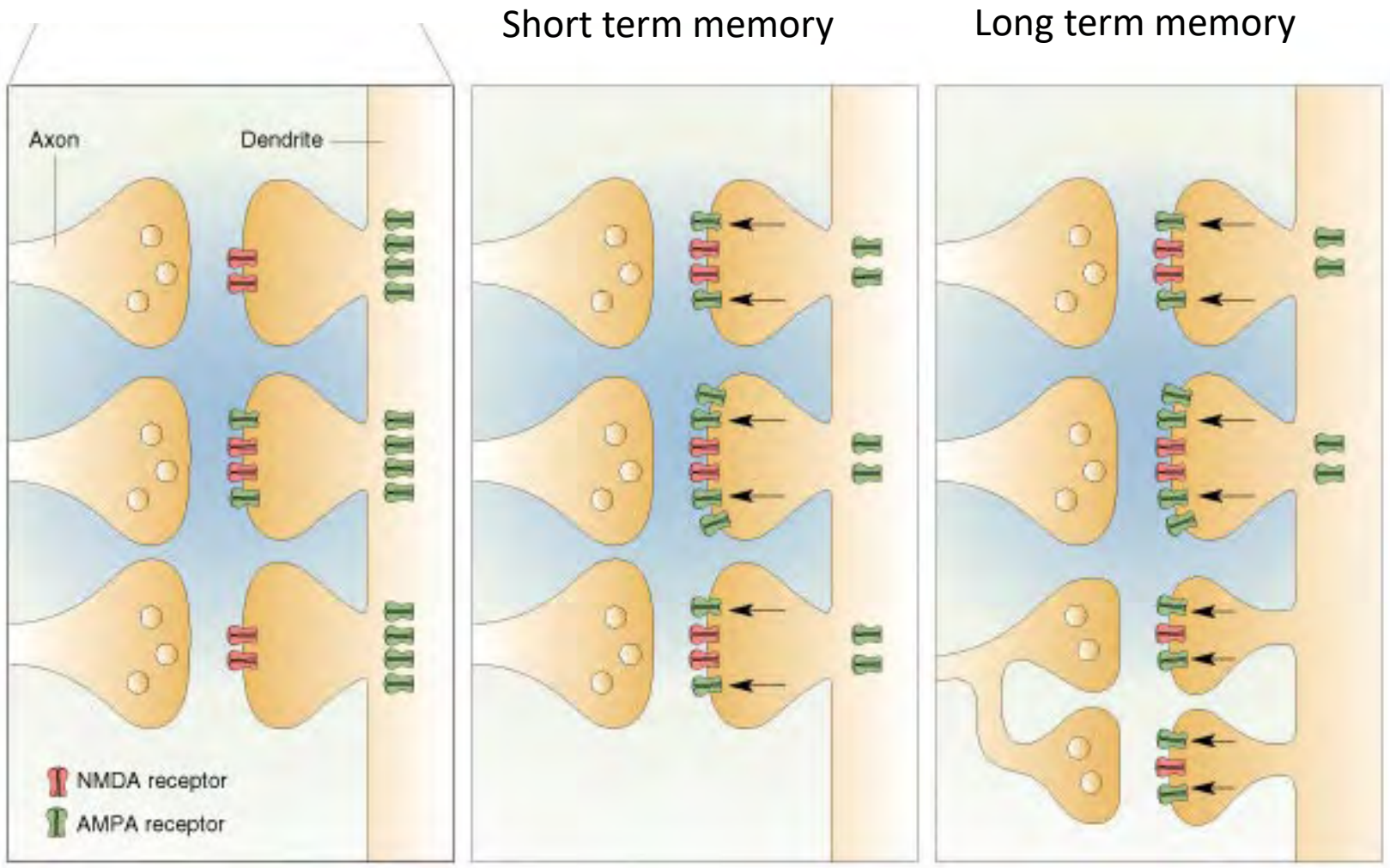
Lakhani, Borich, Jackson, Vavasour, Rauscher, MacKay & Boyd, 2016

Struggle During Learning is Good

We find relationships between the amount of time in early learning

- **Slower change in behaviour leads to larger neuroplastic change in myelin**

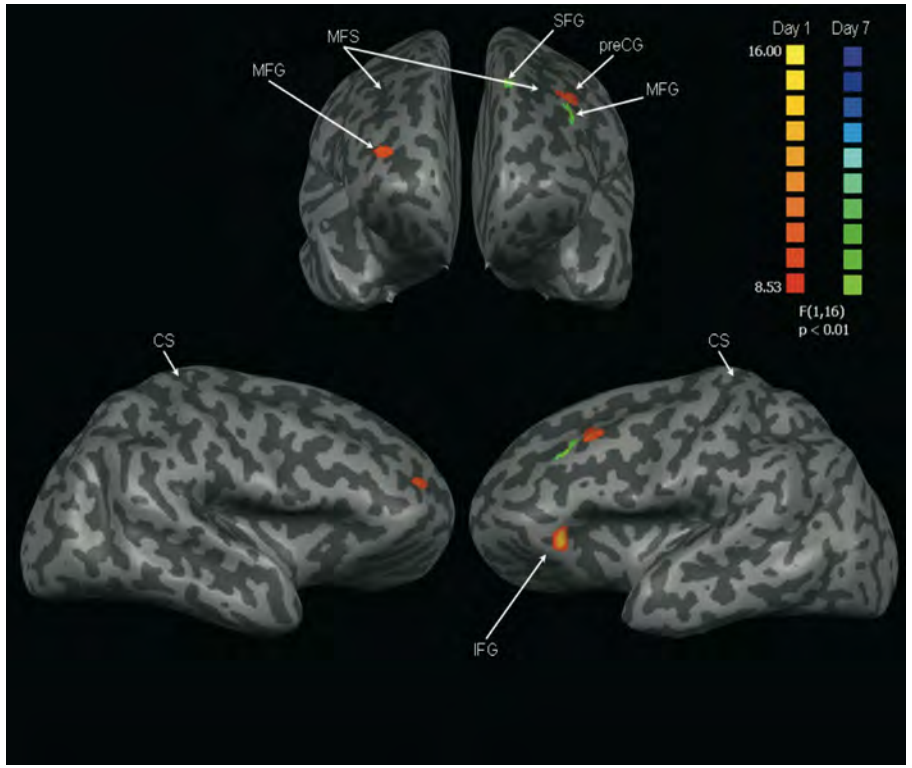
Brain Chemistry and Structure interact to create Long-term Memories



adapted from Kandel, 2013

Brain Function

Task based



Meehan & Boyd, 2011

Resting

Boyd lab, 2016, unpublished

The Developing Brain

- Grey Matter (outer layers of the cortex) achieve maturity early in life
  - Girls age 11; Boys age 12

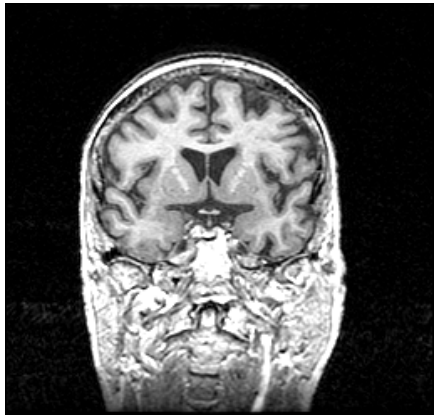
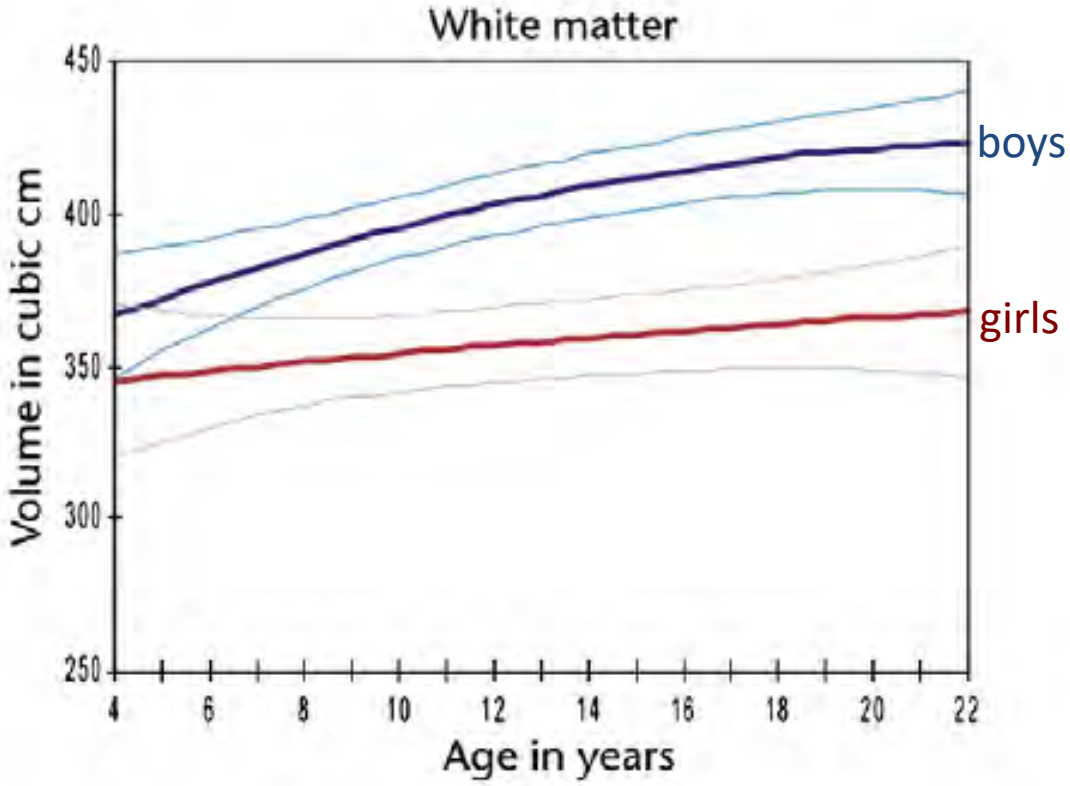


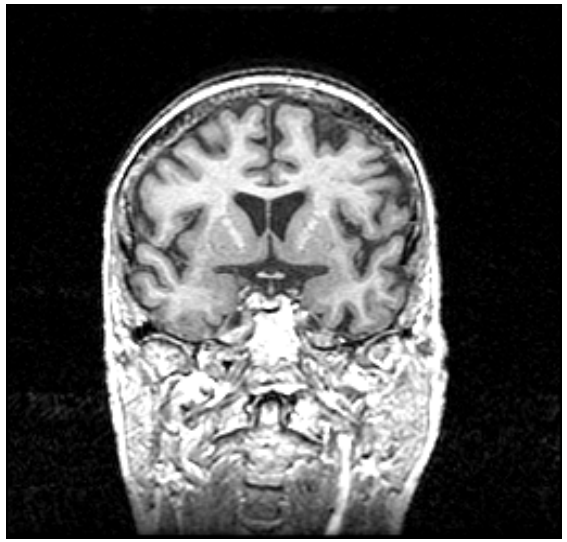
Fig. 4. Age of attaining peak cortical thickness across the cortex in 375 healthy participants ranging in age from five to 25 years (Shaw et al., 2008).

Blakemore 2012

The Developing Brain

- White Matter (connections between cortical areas) achieve maturity later in life and differentially in boys (age 25) vs. girls (age 20)

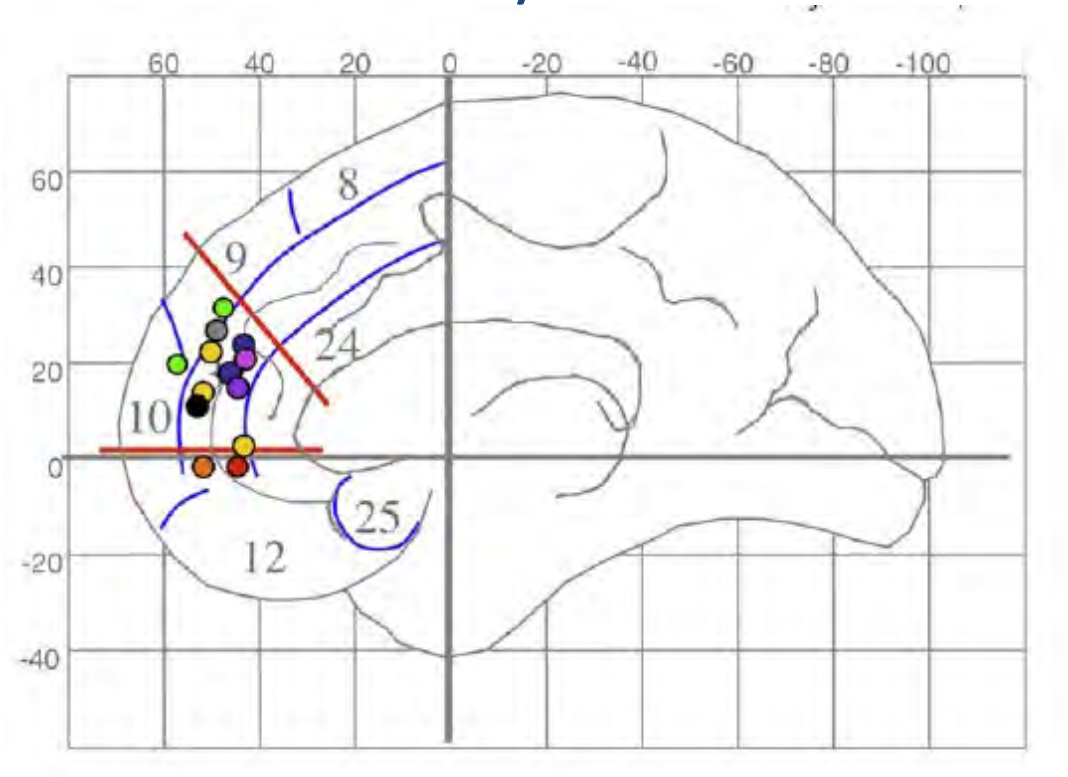




Blakemore 2012

The Developing Brain

- Brain Processing efficiency increases with age
  - Less activity in prefrontal cortex between adolescence and early adulthood



Blakemore 2012

Summary: The Neuroplastic Brain

- All brains are neuroplastic
- Neuroplasticity occurs at the chemical, structural and functional level
- Younger brains are more neuroplastic than older ones
- Yet, our capacity for brain plasticity is maintained throughout adulthood and into old age
- These changes translate into change in behaviour and learning

Part II. Neuroplasticity: Promise and Peril

- Why can’t we learn anything we choose to with ease?
- Why do kids fail in school?
- Why don’t people recover fully after brain damage?

What limits and what facilitates neuroplasticity?

Not all neuroplastic change is positive

- Repetitive use injuries
- Chronic pain
- Drug and/or Alcohol use
- Stress / Anxiety

Back Pain Alters the Sensory Cortex

Chronic back pain leads to:

- Increased cortical reactivity to painful stimuli
- Increased cortical reactivity to non-painful stimuli
- Increased cortical reactivity when body parts other than the back are touched

Flor et al., 1997

Stress Response - Cortisol

The hormone **Cortisol** is secreted by the adrenal glands.

Cortisol is key for:

- Glucose Metabolism
- Regulation of blood pressure
- Insulin release for blood sugar maintenance
- Immune function
- Inflammatory response
- Arousal

And cortisol release can **positively affect memory**, immunity, pain sensitivity…

Stress Response - Cortisol

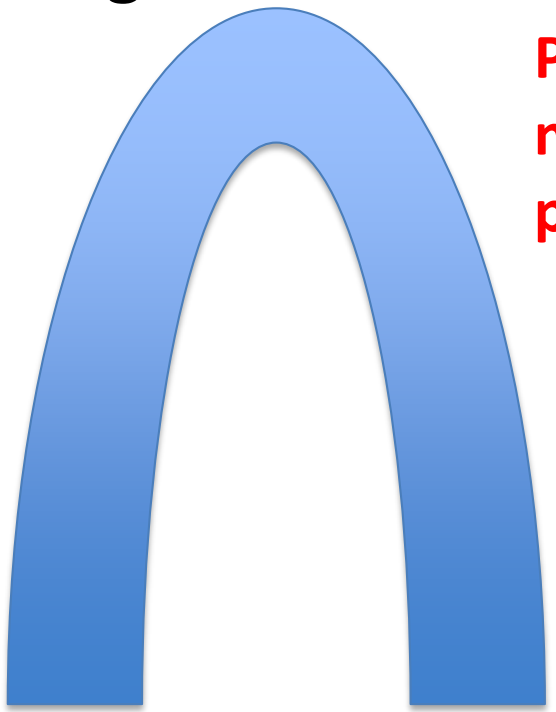
Higher and prolonged levels of cortisol in the bloodstream (with chronic stress) has negative effects:

- **Impaired cognitive performance**
- Suppressed thyroid function
- Blood sugar imbalances (hyperglycemia)
- Decreased bone density
- Decrease in muscle tissue
- High Blood pressure
- Low immunity but high inflammatory responses in the body
- Increased abdominal fat
- Higher levels of “bad” cholesterol (LDL) and lower levels of “good” cholesterol (HDL)

Stress Response and Cortisol

- An inverted "U" relationship with health

Just the Right Amount of Cortisol



Positive effects on memory, immunity, pain sensitivity

Too little Cortisol

Low Motivation
Low Arousal

Too Much Cortisol

Anxiety
Memory impairments
Health Issues – weight gain

Stress, depression and neuroplasticity

- Persistent exposure to stress leads to less brain derived neurotrophic factor (BDNF) and atrophy in key memory structures (hippocampus) of the brain

Managing Stress (and Cortisol)

- Adults who practiced Buddhist meditation significantly decreased cortisol and blood pressure in 6-weeks.
- Six hours of sleep vs. eight increases cortisol in the bloodstream by 50% in adults.
- Exercise: if intense increases cortisol but rebounds to lower levels
  - moderate intensity exercise reduces cortisol
- Children who engage in mindfulness (Mind Up) show higher empathy, more optimism & less depression

The Dose Problem

The dose of practice required to change the brain can be very large

- 9,600 retrievals over 4 weeks (Nudo et al., 1996)
- 10,000 repetitions of skilled movement (myelin; Borich, et al 2013; Lakhani et al., 2016)
- 31,500 repetitions of a sequence (Karni et al., 1995)

Summary: Neuroplasticity, Promise and Peril

- Not all neuroplastic change is beneficial to function or health
- Changing behaviour means changing brain
- Behaviour can remediate negative neuroplastic change
- The dose of practice required to change the brain is large

Part III. Exploiting Neuroplasticity

Exercise and Brain Plasticity

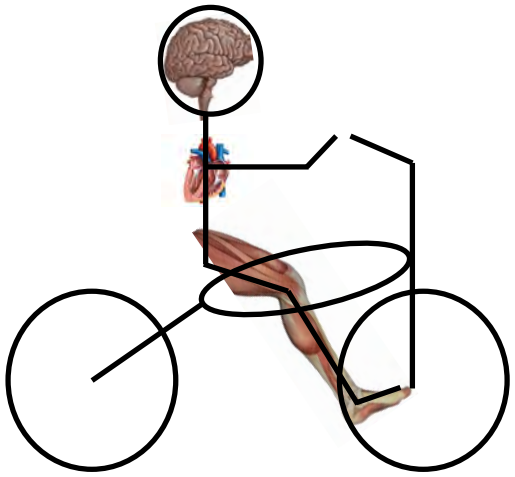
Exercise Enhances…

- Blood Flow
- Blood Vessel Formation
- Cerebral White and Grey Matter
- Neuron and Synapse Growth
- Neural Growth Factors
- Neurotransmitters

Non-Exerciser

Exerciser

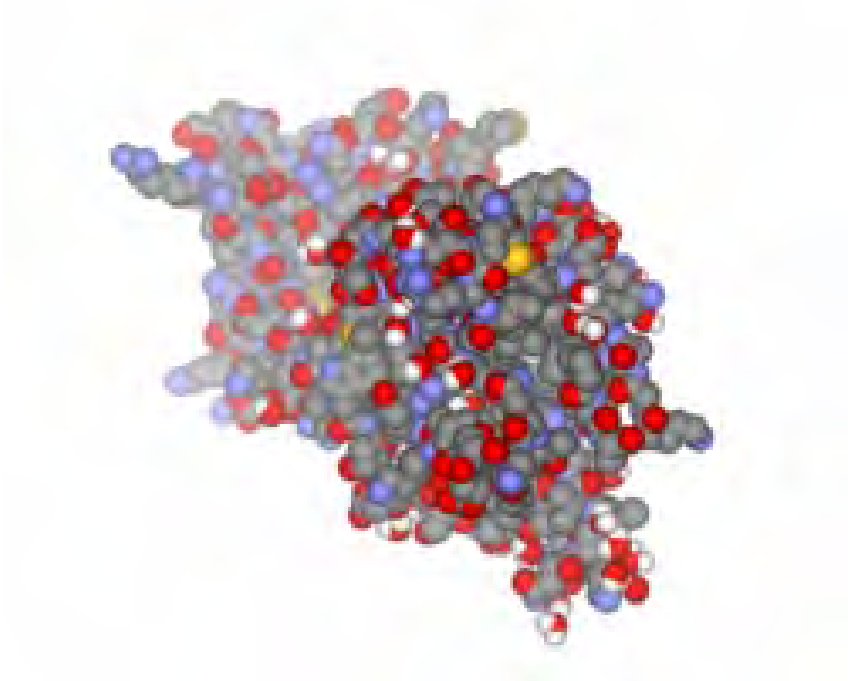
Priming the Brain to Learn

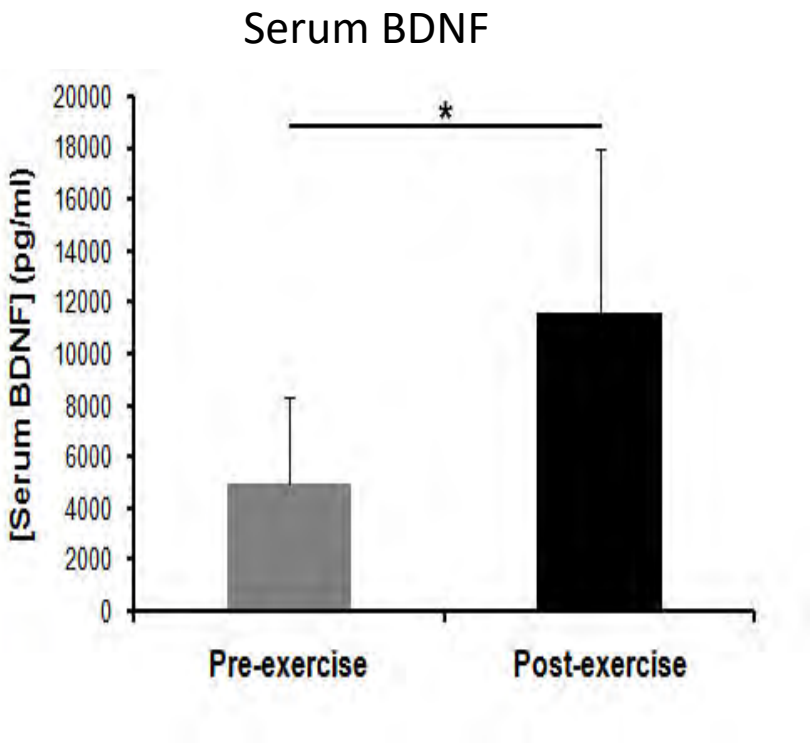


Exercise, Mang et al, 2016

3 X 3 minutes 90% $V0_2$ max Cycling

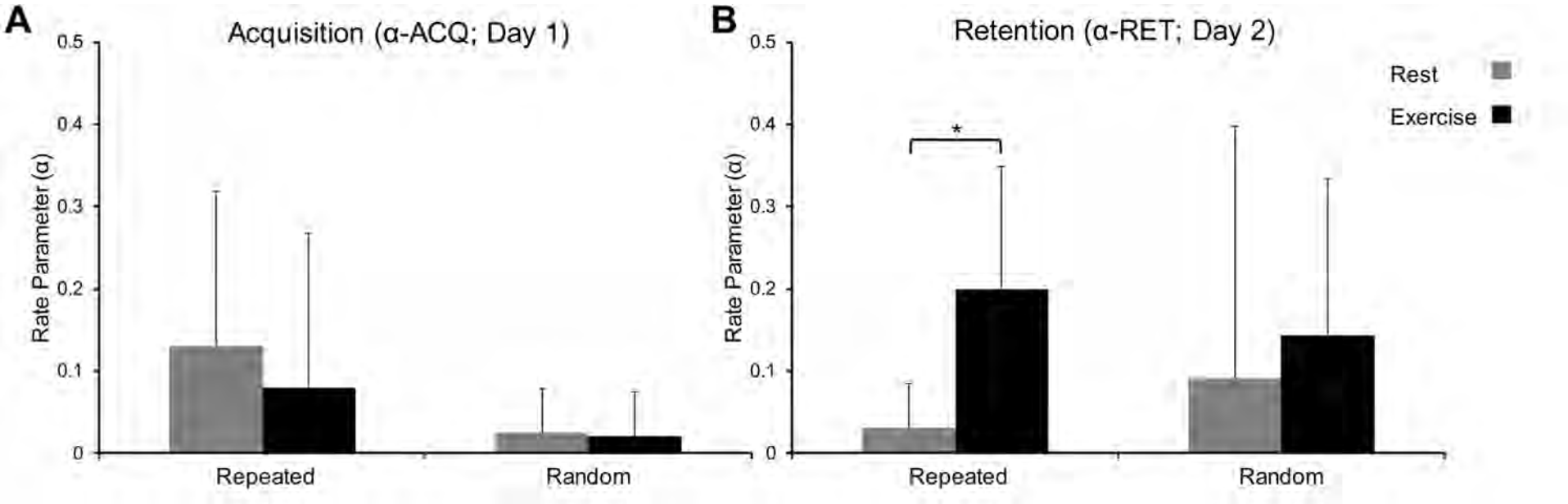
A single session of aerobic exercise enhances brain derived neurotrophic factor





Mang, Snow, Campbell, Ross & Boyd, 2014

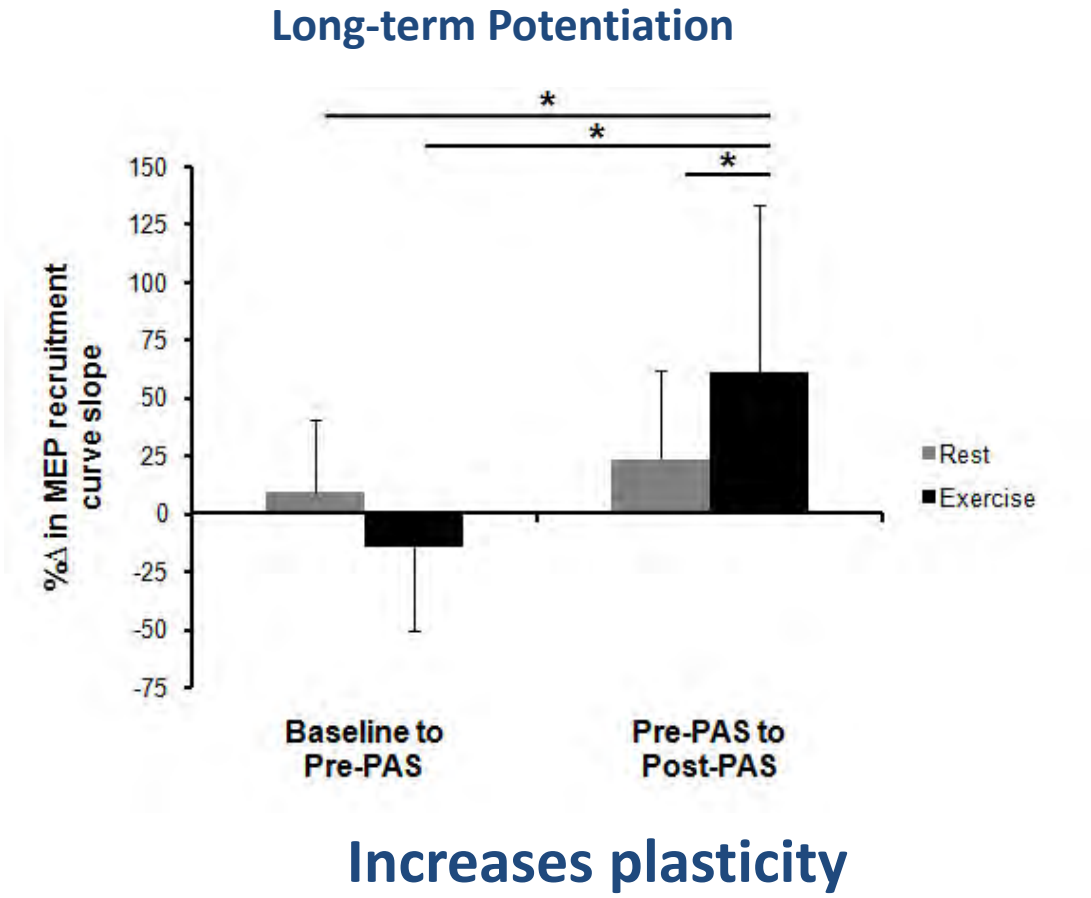
A single bout of exercise facilitates learning through motor memory consolidation



Learning effects are only evident after a 24-hour delay.

Mang et al, MSSE, 2017
Mang et al, Journal of Applied Physiology, 2014

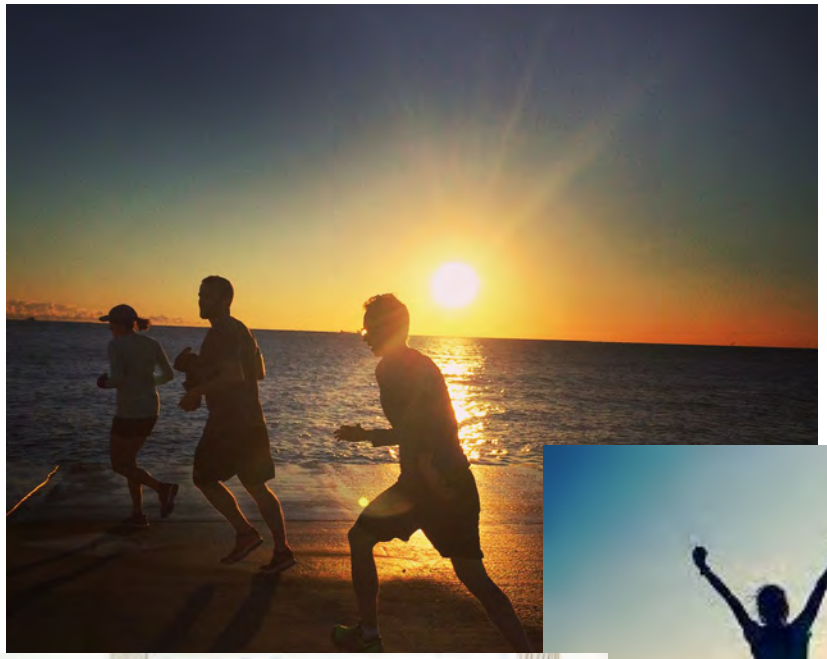
How does exercise work on the brain?

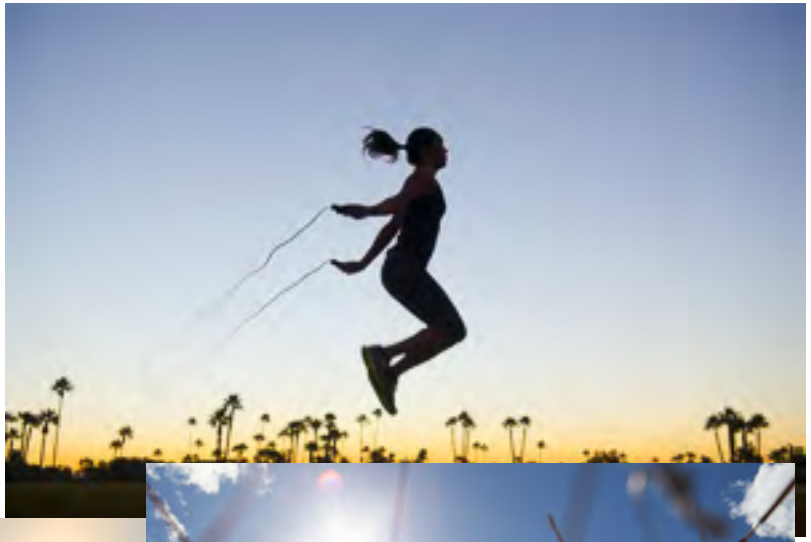


Increases plasticity

Mang, Snow, Campbell, Ross & Boyd, 2014; Neva, Mang & Boyd, 2015

Many forms of Exercise promote brain health





Sleep

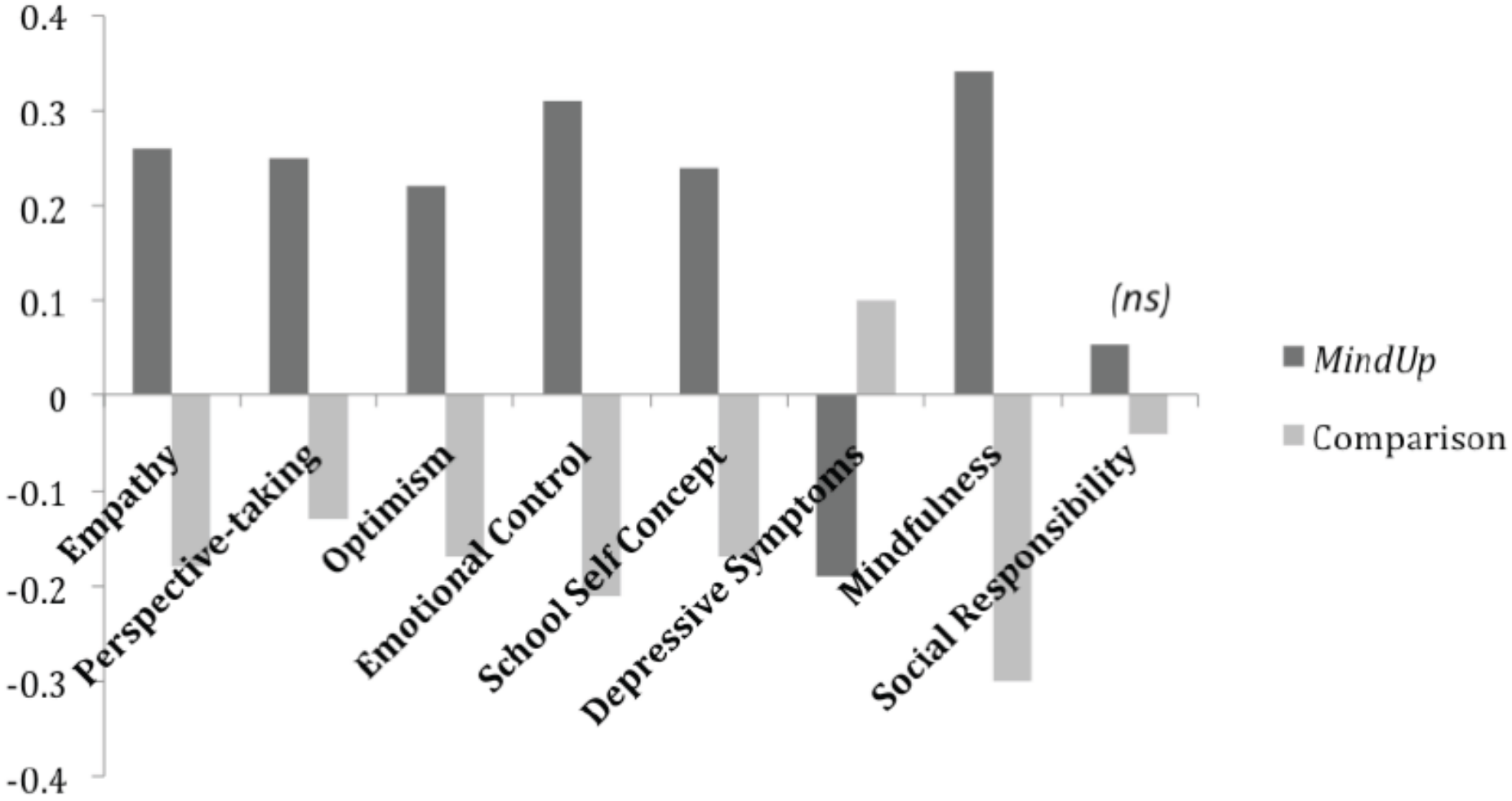
All mammals sleep but it is not entirely clear why

Recent work points to a role for sleep in the encoding and consolidation of memories

One hypothesis is that sleep contributes to processes of memory and brain plasticity

- Sleep dependent memory processing

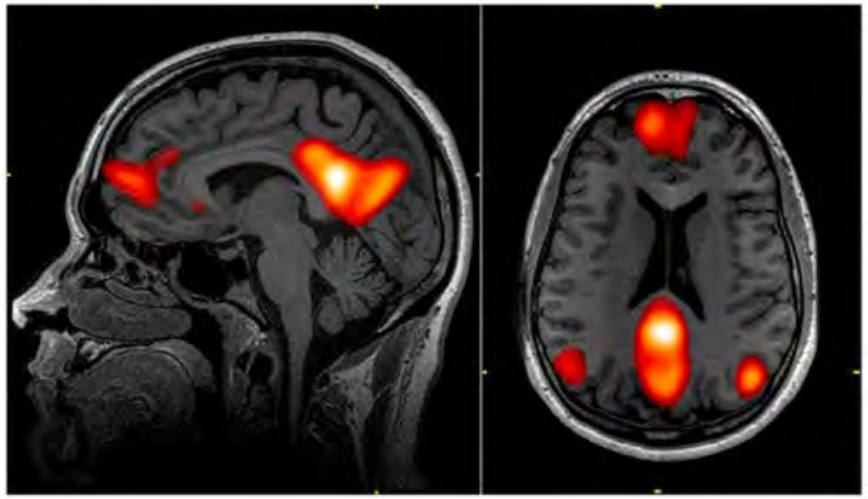
Mindfulness: Mind Up



Schonert-Reichl 2011

Why Mindfulness…

- Not entirely clear
- Practice of mindfulness may allow the brain some time to revert to the default mode network in our brains
- Links between mind-wandering, creativity and default mode being explored

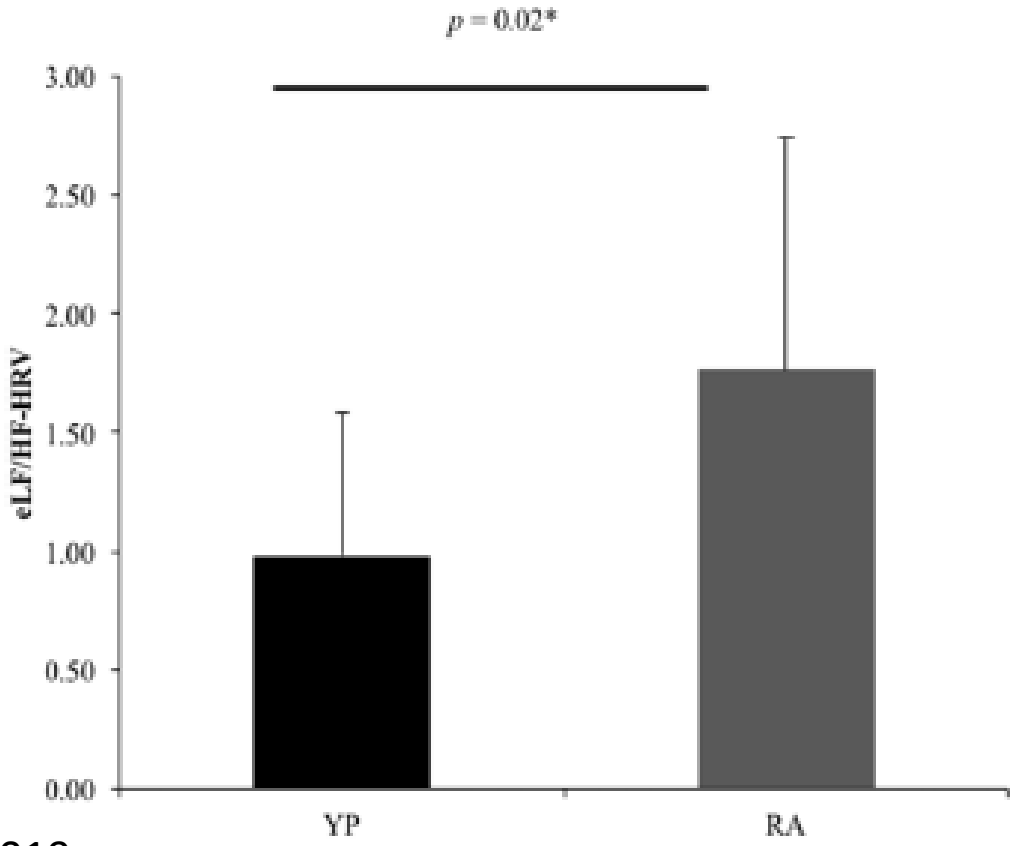


Yoga changes the brain's response to emotion (and stress)

Wadden et al., 2019

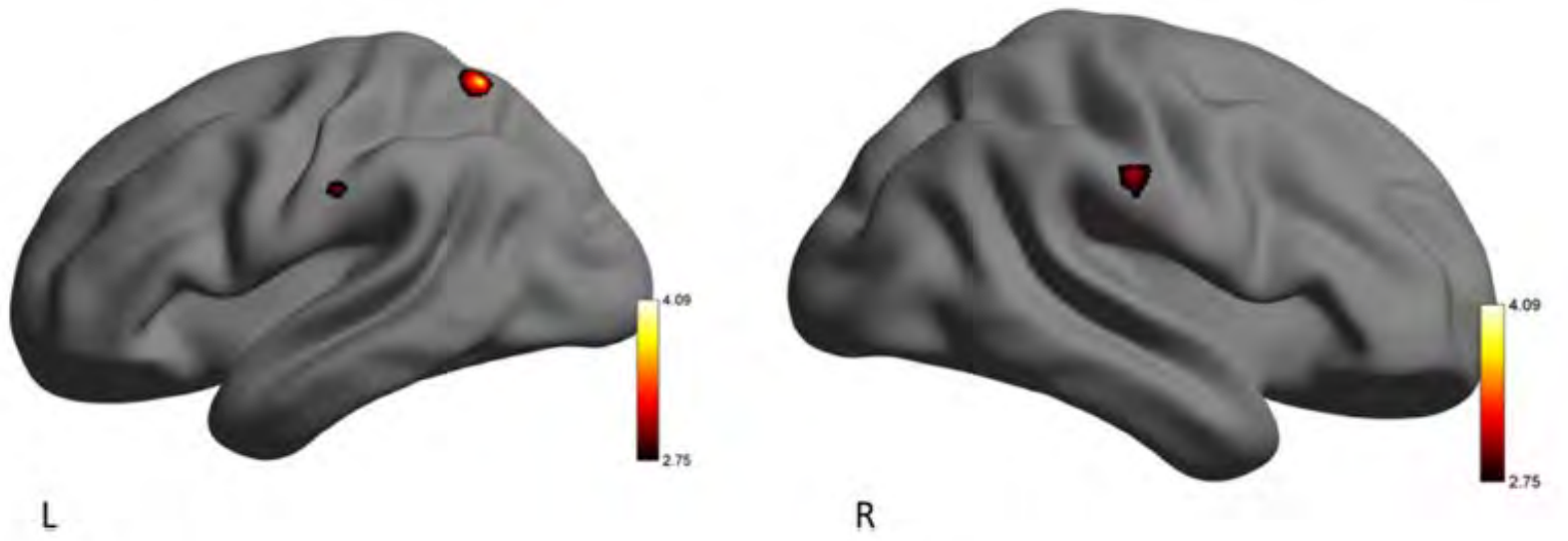
Heart Rate Variability

High heart rate variability shows an adaptive or healthy response to stress in Yogi's



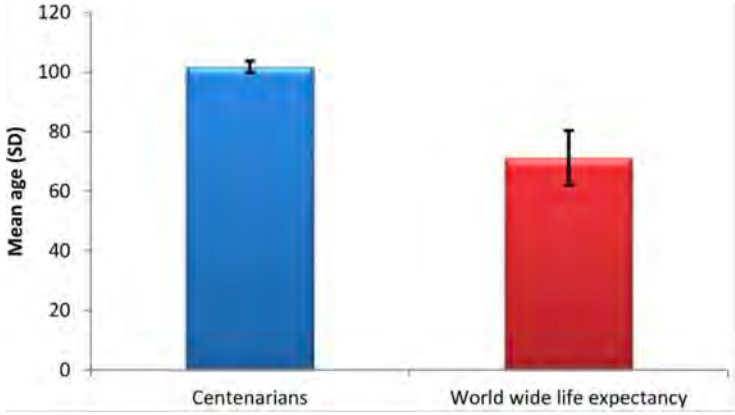
Wadden et al., 2019

People who practice Yoga show a more adaptive emotional response as indicated by larger activity in the amygdala as compared to Recreational Athletes



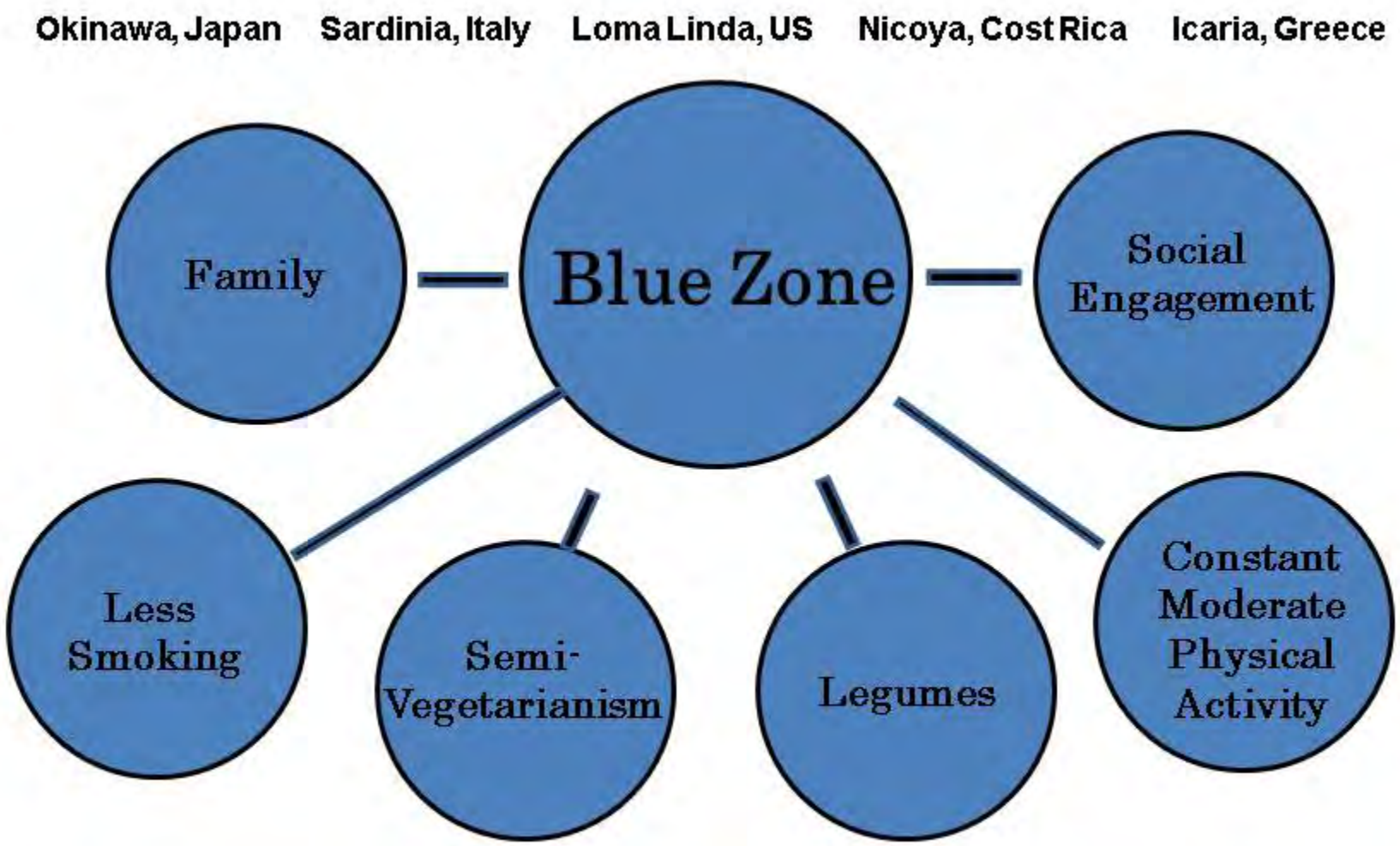
Wadden et al., 2019

Where you live also matters: “Blue Zones”



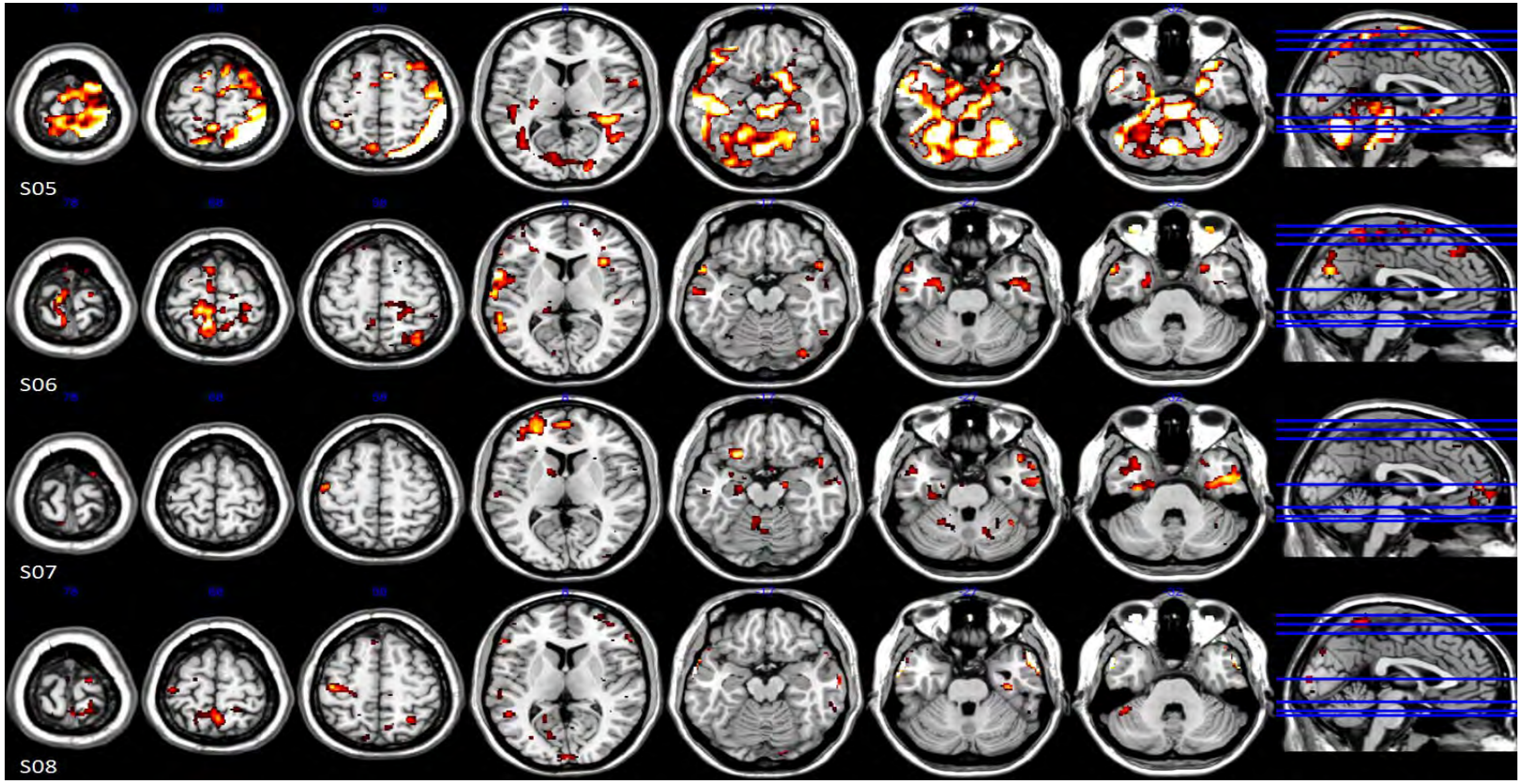
Blue Zones are areas of the world where people live to be 100

What is special about ”Blue Zones”



One size does not fit all:

Variability in brain response during learning



Wadden, Woodward & Boyd, 2015

Summary: Exploiting Neuroplasticity

- Practice! Behaviour is the largest stimulant of neuroplastic change
- Exercise primes the brain to learn
  - Both acute and chronic effects
  - Exercise reduces cortisol and increases BDNF
  - Exercise facilitates an overall environment of excitability in the brain that favors plasticity
- Each of us is changing our brain uniquely – effective interventions need to reflect this individuality

Personalized Learning

The uniqueness of your brain affects you as both teacher and learner

- A challenge is to figure out what stimulates positive neuroplasticity and learning for you
- And what makes you flourish, prosper and progress towards your goals
- Learn to learn

Brain Health and Repair

Brain Behaviour lab @UBC_BrainLab
Practice what we preach

a place of mind

THE UNIVERSITY OF BRITISH COLUMBIA