Got Stress? The Science of Measuring and Improving Meditation
Exercises and Science

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Meditation: from practice to health

His Holiness the Dalai Lama
Credit: cherylschirillo.com

East Bay Meditation Center, Oakland, CA,
Credit: NY Times

- Meditation exercises are ancient Buddhist practices that are increasingly used to cultivate health
  - 14.3% of US adults in 2017 (~35 million, Clarke et al., 2018)

Meditation: from practice to health

Mind & Life Dialogue XXX
Bylakuppe, India, 2015

- Meditation practices have been adapted to treat mental and physical health conditions (stress, depression, anxiety, pain, cancer)
  - Moderate improvements (Van Dam et al., 2017)
- Meditation is not a cure-all, and different people respond in different ways
  - How do we understand these processes?

Meditation – Internal tools for the
Power of Transformation

Change internal attention to change outer world:

1) Slow it Down

- Observe, Bring Awareness
- Open to more info
- Identify experiences
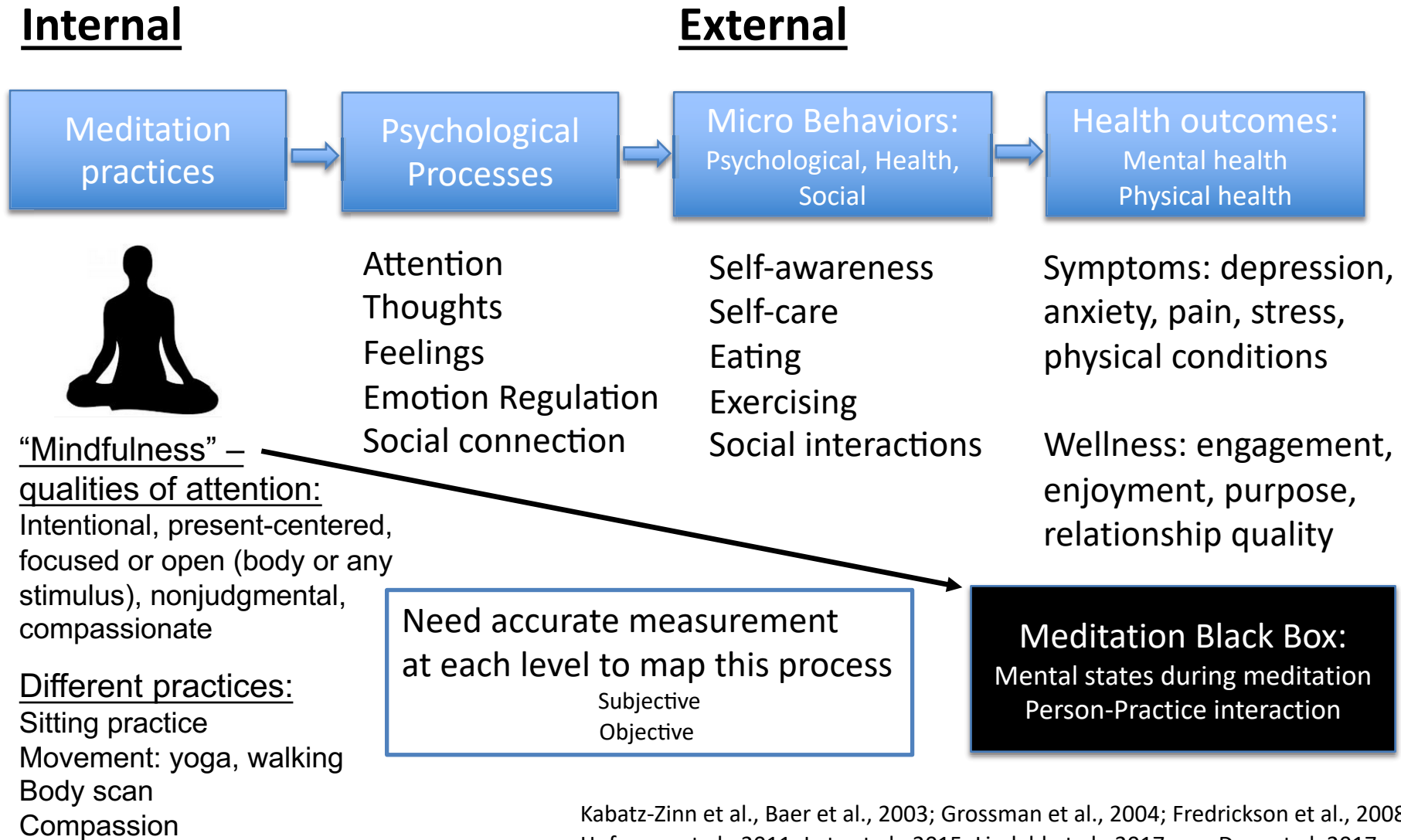
Breath and Body Meditation
Open monitoring

2) Bring Kindness

- Honor and integrate selves
- <u>Choose a better way</u>

Compassion Meditation

Art: okclipart
Andrew Glencross

Measurement Challenge:
From internal practice to external change

Internal   **External**

Meditation practices	Psychological Processes	Micro Behaviors: Psychological, Health, Social	Health outcomes: Mental health Physical health

Attention
Thoughts
Feelings
Emotion Regulation
Social connection

Self-awareness
Self-care
Eating
Exercising
Social interactions

Symptoms: depression, anxiety, pain, stress, physical conditions

Wellness: engagement, enjoyment, purpose, relationship quality

"Mindfulness" – qualities of attention:
Intentional, present-centered, focused or open (body or any stimulus), nonjudgmental, compassionate

Different practices:
Sitting practice
Movement: yoga, walking
Body scan
Compassion

Need accurate measurement at each level to map this process
Subjective
Objective

Meditation Black Box:
Mental states during meditation
Person-Practice interaction

Kabatz-Zinn et al., Baer et al., 2003; Grossman et al., 2004; Fredrickson et al., 2008; Hofmann et al., 2011; Lutz et al., 2015; Lindahl et al., 2017; van Dam et al, 2017

Neuroplasticity:
Meditation to change mental habits

- Inherent to the philosophy of meditation
  - We have the ability to change the way our minds work and how we act
- **Neuroplasticity**
  - Our brains are one of the most responsive organs to the environment
  - Our brains (and biology) are not fixed
  - Adults are able to generate new neurons in the hippocampus (Erikkson et al., 1998)
  - Brain changes seen due to motor training (juggling), musical training, cognitive training, now we are beginning to see with meditation training (Davidson & McEwen, 2012, Fox et al., 2016)
- As scientists, how do we study and measure these changes?

Integrating real-world experience:
No one-to-one mapping of practice and change

- Meditation doesn't "do" _____ [fill in your favorite amazing effect]
- Meditation cannot do anything independently of the person who is practicing. The person does something, not meditation.
- Each person responds to learning meditation differently (group averages simplify the story)
- **Every person is different in their**
  - goals for meditation
  - attentional capacities and personalities
  - responses to meditation practices
  - responses to teachers/modalities
  - ways of continuing practice
  - ways of applying meditative qualities to everyday lives

Measuring the Immeasurable

- Meditation: the ultimate black box
- The promise of neuroscience to elucidate the black box
  - More objective
  - "Read the mind" using neural data
  - From groups to individuals
- Examples:
  - Compassion meditation
  - Breath-focused meditation
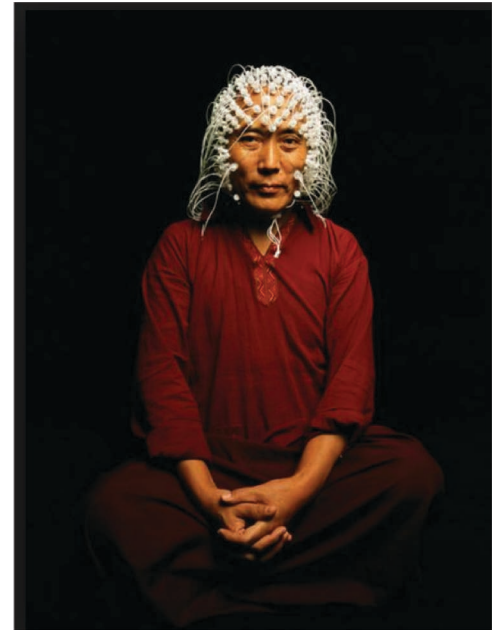
Credit: National Geographic

Mindfulness and Meditation Practices: Multi-faceted nature of attention

Meta-Awareness

Present-Centered

Object or Focus

Attitudinal components: Non-Judgmental, Compassionate

Lutz, Jha, et *al.*, 2015
Kabat-Zinn *et al.*

Artist: Weng, 1997
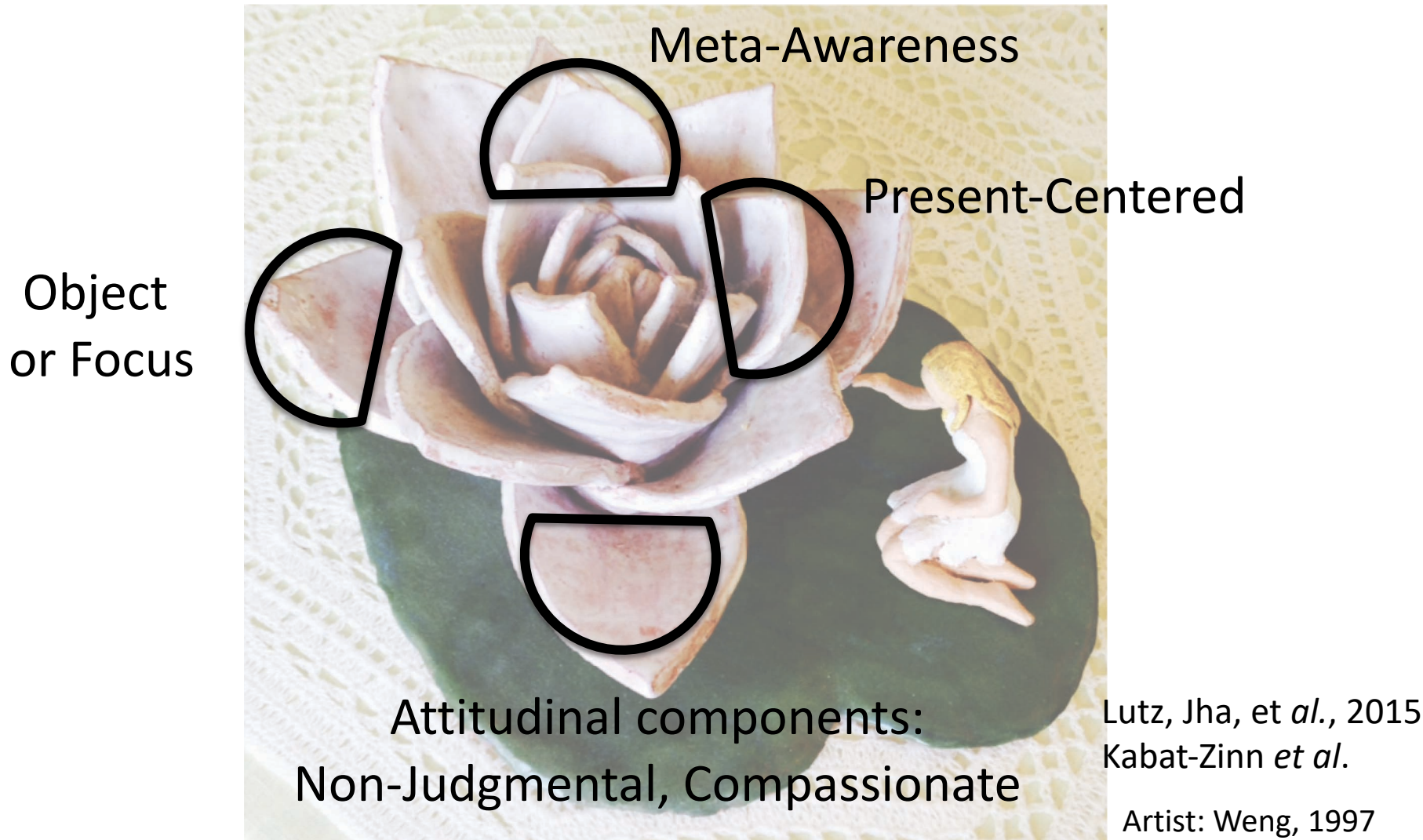
Lovingkindness and Compassion Meditation

Compassion is the feeling that arises when witnessing another's suffering and that motivates a desire to help (Goetz et al., 2010)

Relationships and Health

House et al.,1988; Uchino, Cacioppo & Kiecolt-Glaser, 1996;
Cohen & Wills, 1985; Holdt-Lunstad et al. 2010; Copeland et al. 2013; Alloy et al., 2001

Lovingkindness and Compassion Meditation

Improve relationship to self and others

Lovingkindness – wishing well-being

Compassion – caring for and wishing relief from suffering

Compassion: A route to healthier relationships

Compassion is described as "the <u>feeling</u> that arises in <u>witnessing another's suffering</u> and that motivates a subsequent <u>desire to help</u>" (Goetz et al., 2010)

1. SITUATION
Witnessing Suffering

2. EMOTION/MOTIVATION
Feeling(?), Desire to help

3. ACTION
Prosocial Behavior
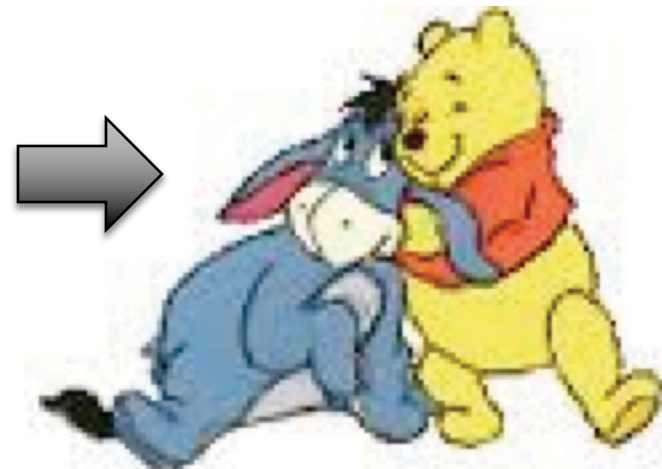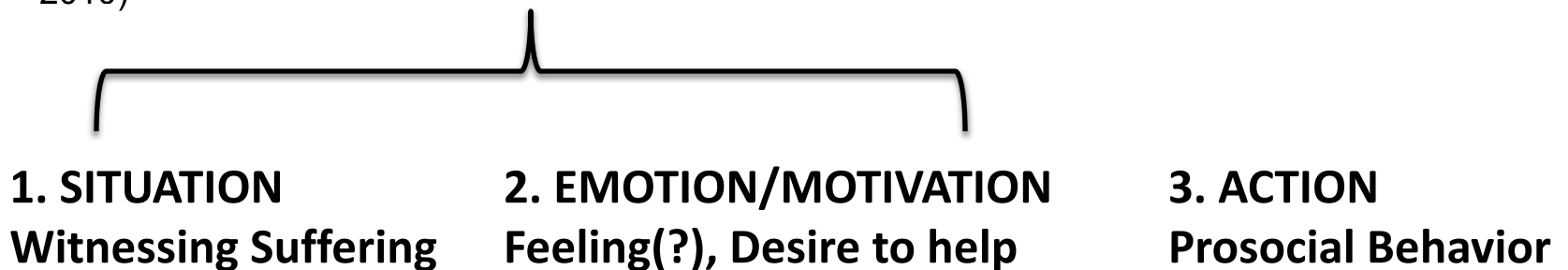
Compassion Meditation
A route to better relationships

Loved One

Self

Stranger
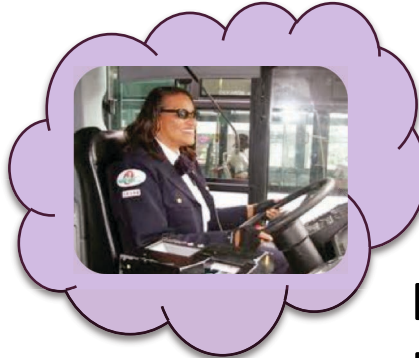
Difficult Person

Envision suffering
Wish relief from suffering

Phrases:
"May you be free from suffering.
May you have joy and ease."

Bodily awareness
Light visualization

REJECT!

Salzberg, 1995
Davidson & Harrington, 2001
Weng et al., 2013

Strengthening the Compassion Muscle

Loved One ⟶ Difficult Person

REJECT!

How does compassion meditation impact the brain and helping others?

Compassion Practice   Real-world behavior
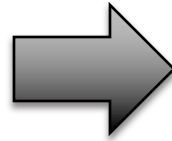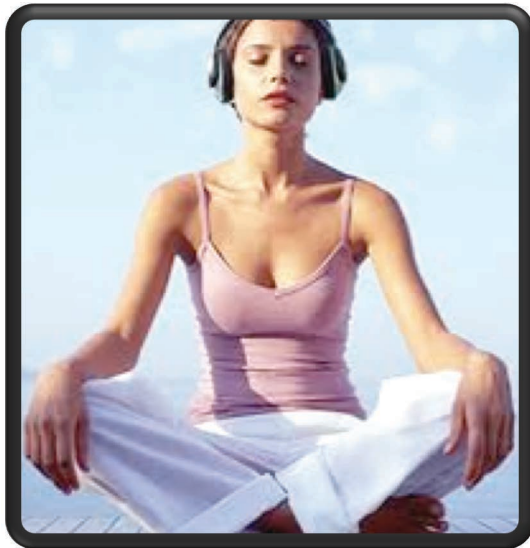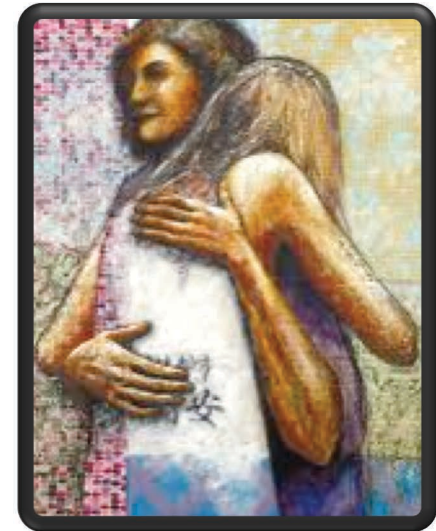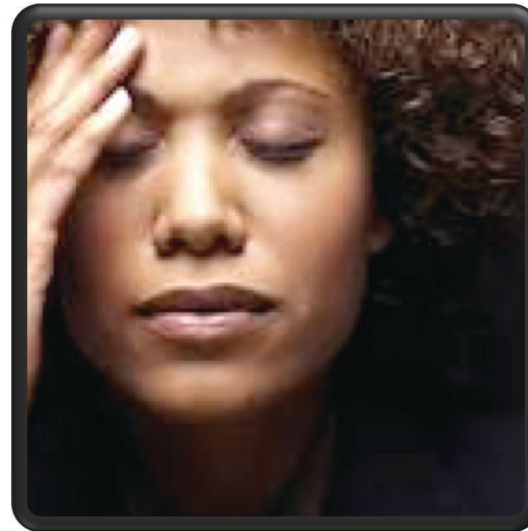
Compassion experts
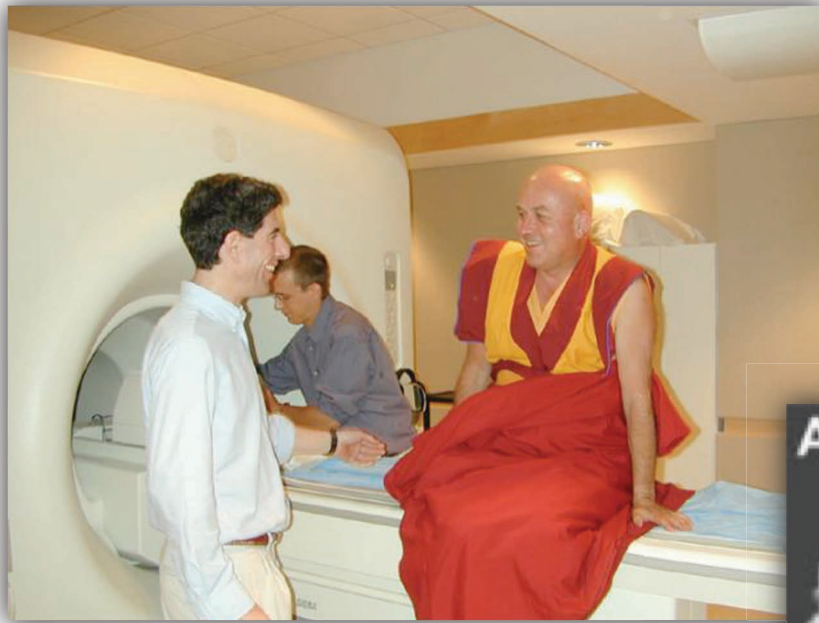
Functional magnetic resonance Imaging (fMRI): uses magnetic energy to estimate levels of oxygen of blood in the brain
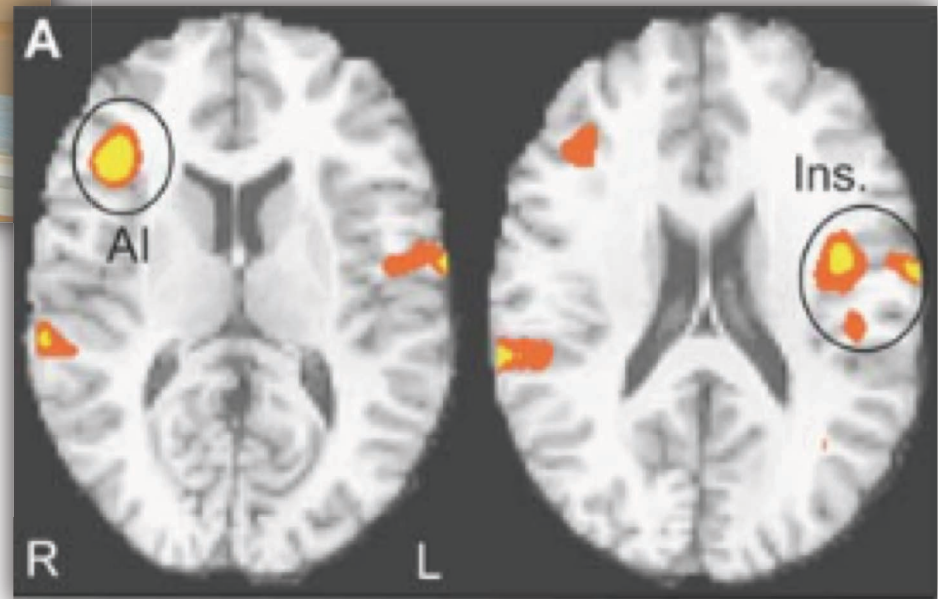
Insula responds more to sounds of suffering

Lutz, Davidson et al., 2008; 2009

What about people like you and me?
Does compassion meditation change our brains and how we treat others?

Framework
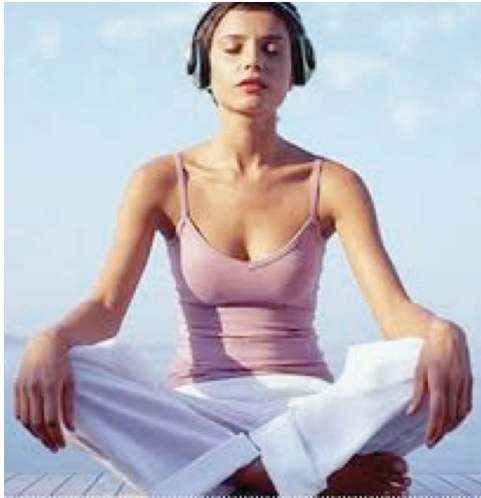
Compassion meditation increases compassion

Which changes brain activity

And will increase real-world prosocial behavior

How do we study Compassion Training?

Before   **After**

30/min day on the Internet
for 2 weeks

**Random
Assignment**

Compassion Training (n=20)

Reappraisal Training (n=21)

Measuring compassionate behavior:
Redistribution Game

$10

A

+ $1

$0

B

- $$

+ $$

C

- $

Interaction 1:
**Unfair
Interaction**

Interaction 2:
**Altruistic
Redistribution**
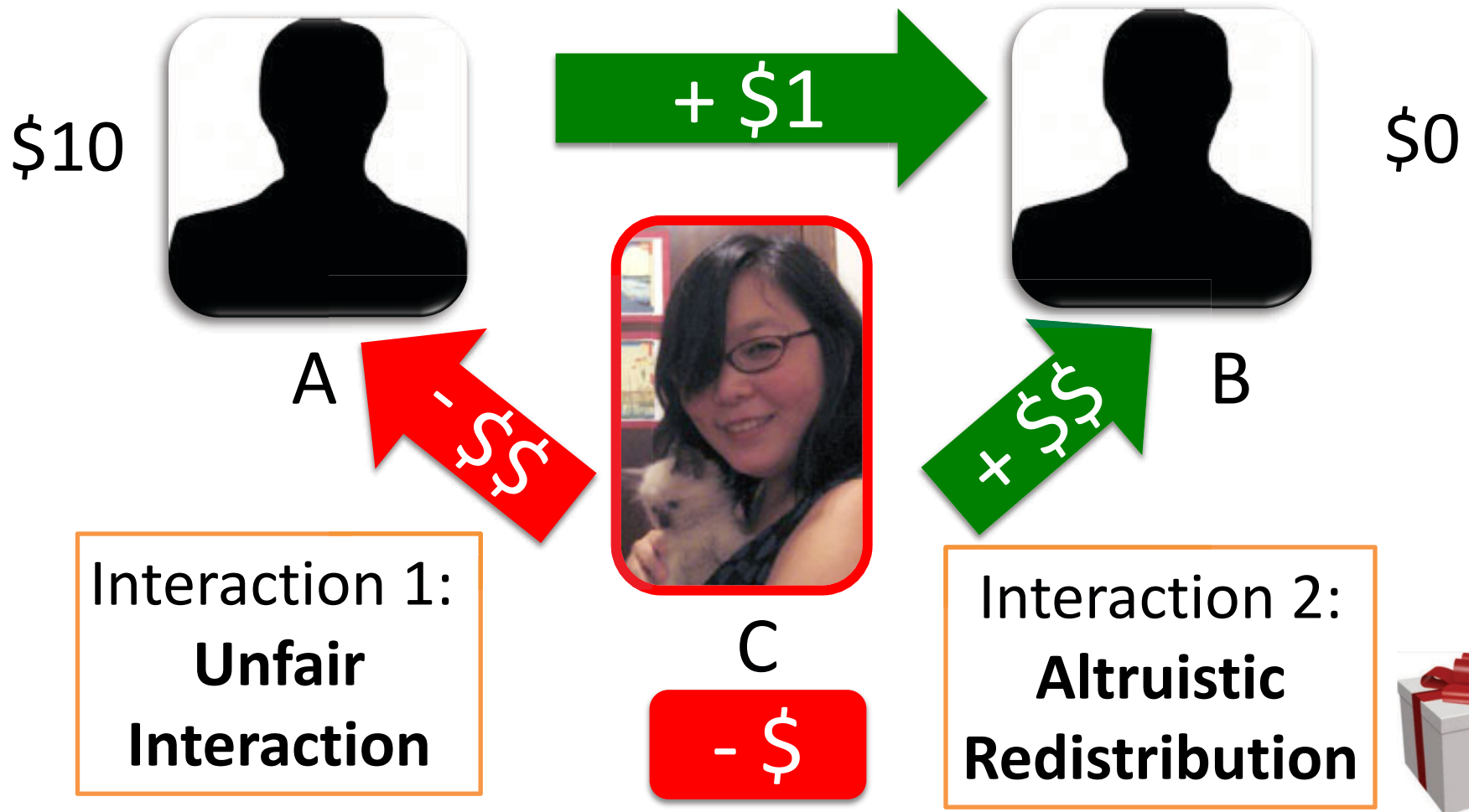
Anonymous online interface

Decision Making Task

Participant 1 made his/her decision and **transferred 10 points** to Participant 2.

How do you want to divide up your points?

How many of your 50 points do you want t
(you may only spend up to 45)?

I transfer | Insert Amount...
I transfer | ...
And keep | ...

Click he
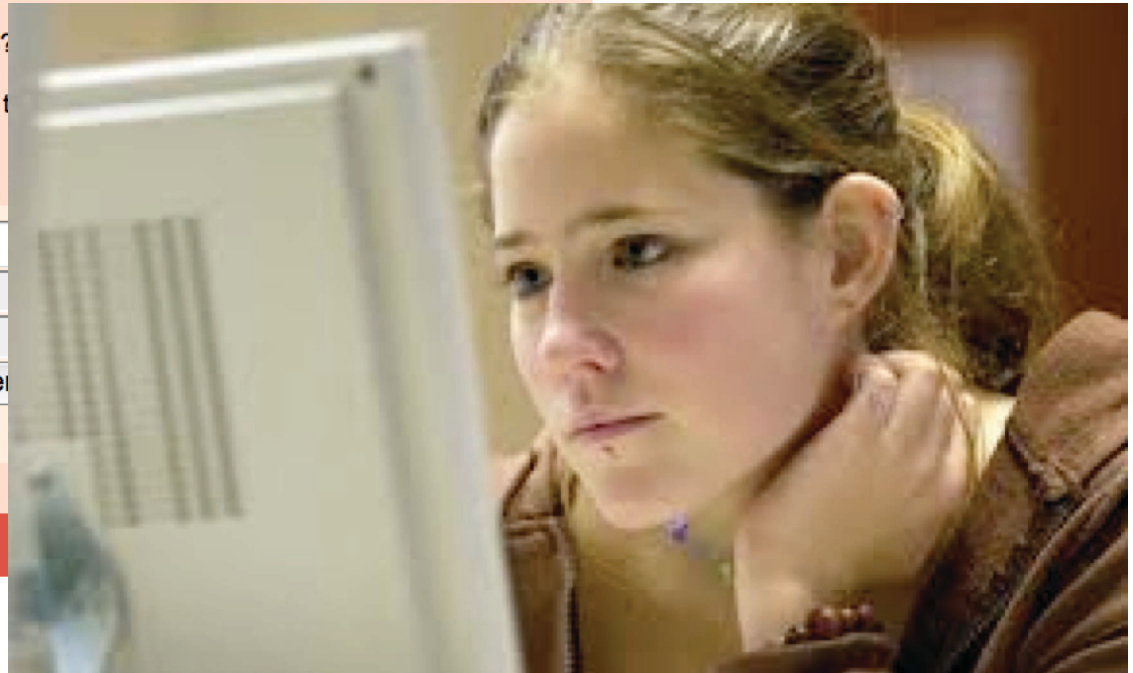
Signed separate IRB, solitary playing,
deception used to standardize dictator transfers, n = 41/56
Redistribution administered first, Helping and Punishment randomized

Does compassion training increase altruistic Redistribution?

Compassion meditation makes people more altruistic

Control
$0.62
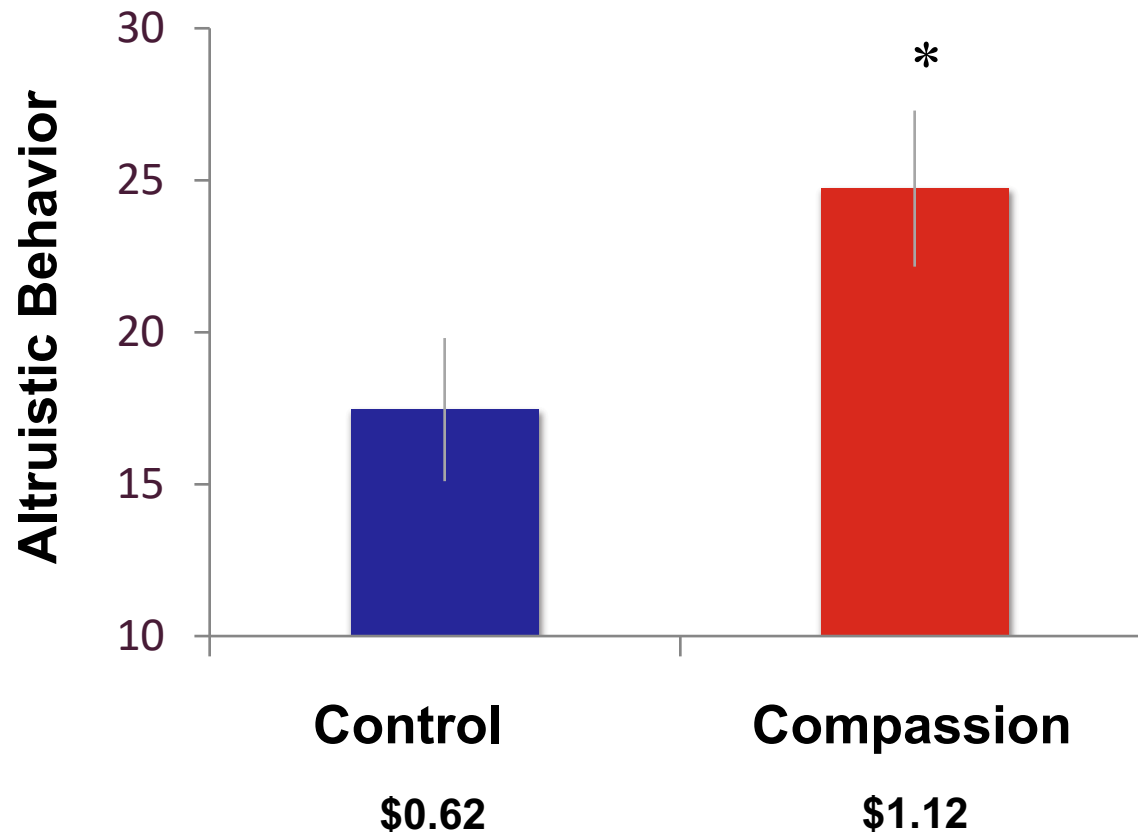
Compassion
$1.12

Weng, Fox, Shackman, Stodola, Caldwell, Olson, Rogers & Davidson
Psychological Science (2013)

Functional MRI:
Before and After Training

Compassion

12 s

5-11 s

12 s

Pictures:
Suffering or Neutral
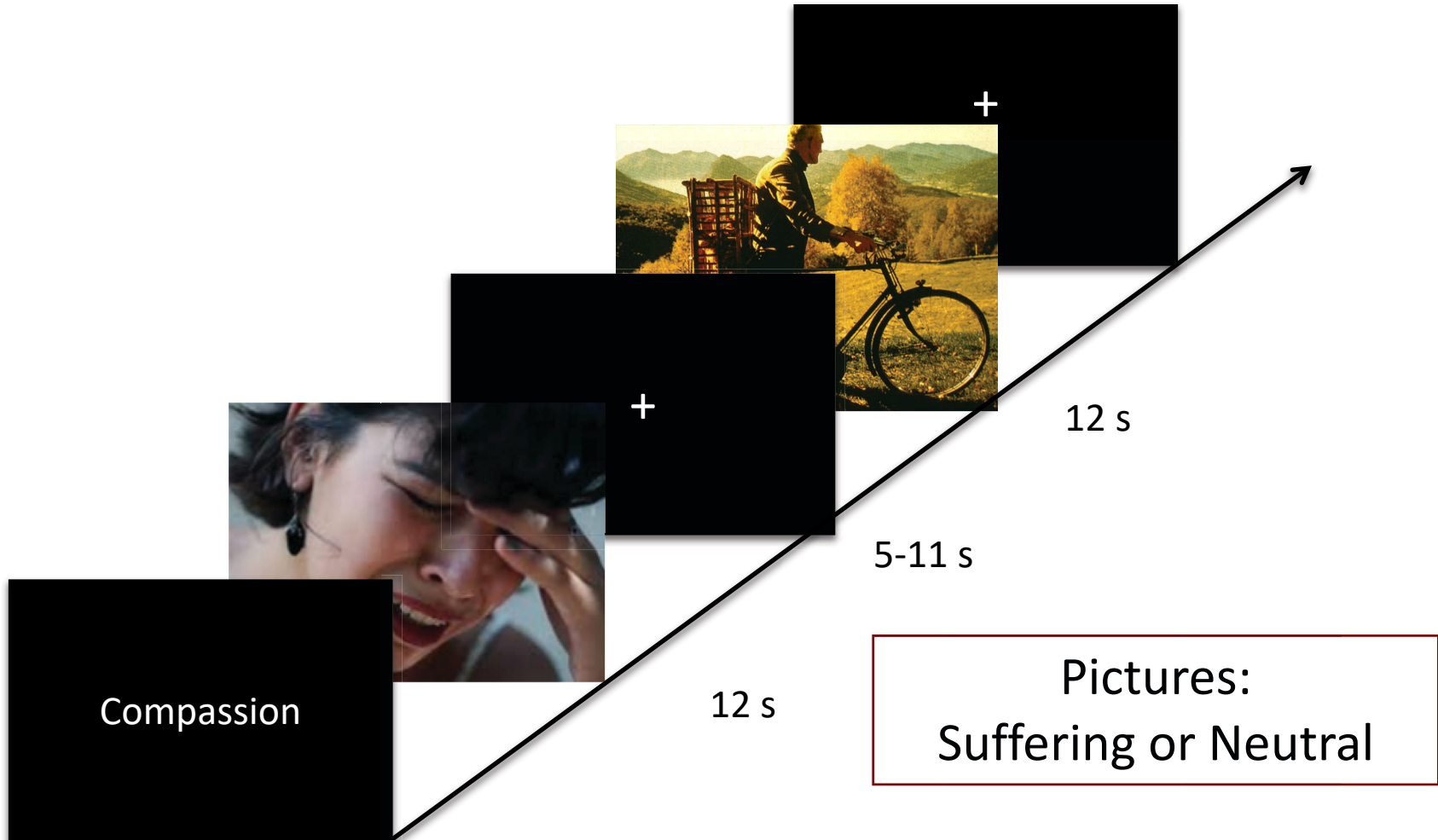
Mind & Life 2012: "Effortful Compassion"

Compassionate Brain Changes – Emotion Regulation

⬆ Empathic Concern
⬇ Personal Distress
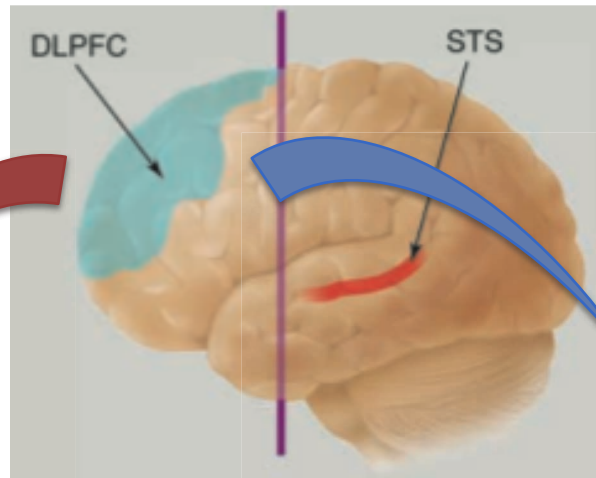
⬆Dorsolateral Prefrontal Cortex (DLPFC)
(emotion regulation, self-control)

⬇ Amygdala
(arousal, distress)

⬆ Insula
(empathy, Interoception)
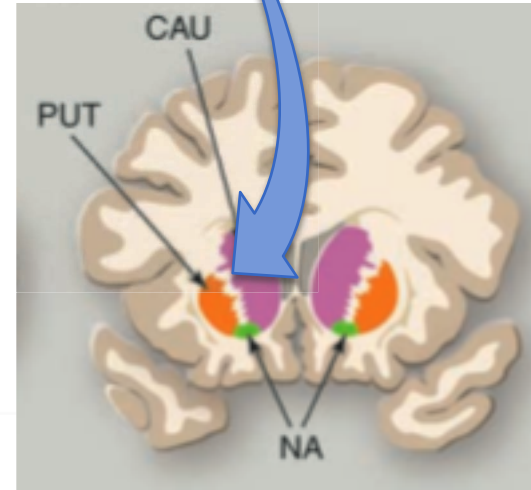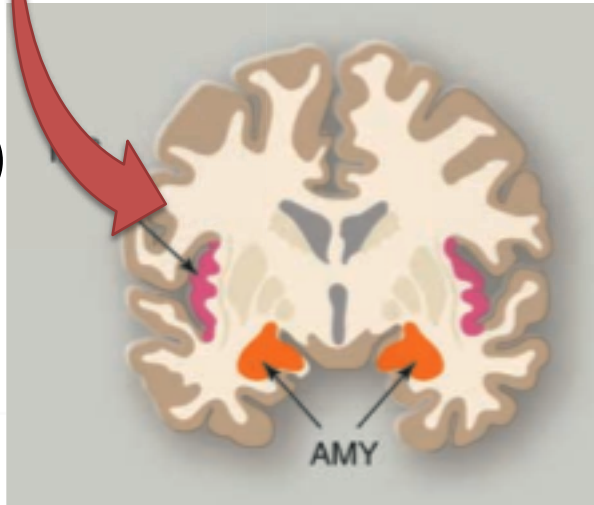
⬆ Nucleus Accumbens
(donations, social reward)

Batson, 1991; Eisenberg et al. 2006; Sanfey, 2007; Urry et al., 2006; Wager et al., 2008; Miller & Cohen, 2001; Harbaugh et al., 2005; Wager et al. 2008; Lutz et al. 2008; Singer et al. 2004, 2006; Hein et al. 2010

fMRI Data Analysis:

Identify neural changes that predict redistribution differently between groups

Group (COM, REP) × Redistribution Interaction

Post
(Suffering-Neutral)

Pre
(Suffering-Neutral)

Compassion meditation increases giving by changing brain responses to suffering

↑ **Parietal Cortex**   ↑ **Prefrontal Cortex**
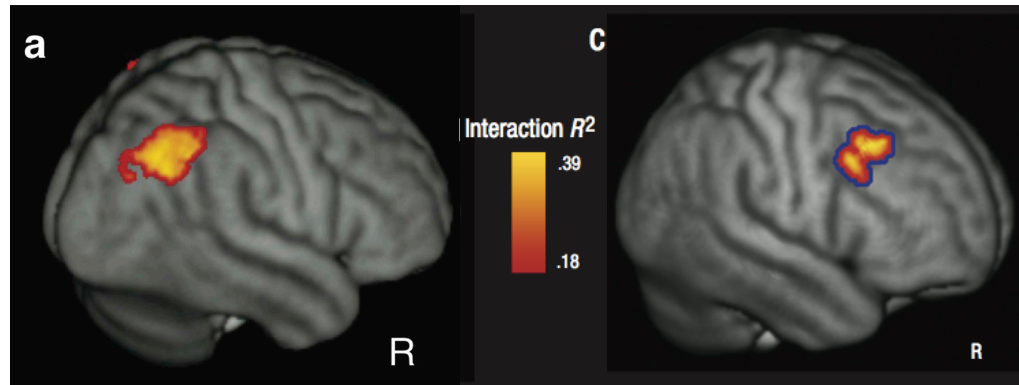
Empathy ("Mirror Neuron") Emotion Regulation

Gives More $
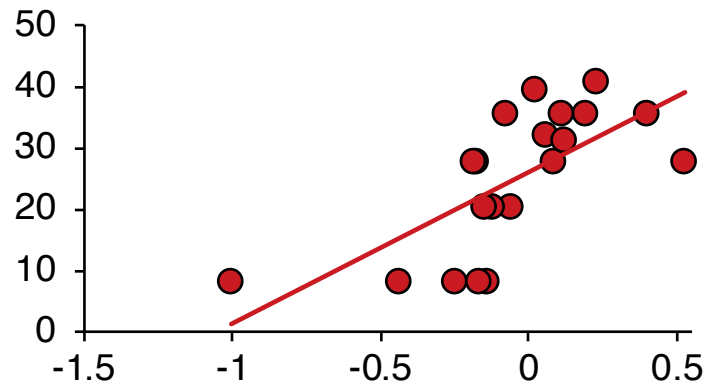
Brain Increases

People who changed their brains the most were the most giving

Weng *et al.*, 2013

Compassion meditation involves emotion regulation:
Altruism predicted by PFC-Nucleus Accumbens Connectivity
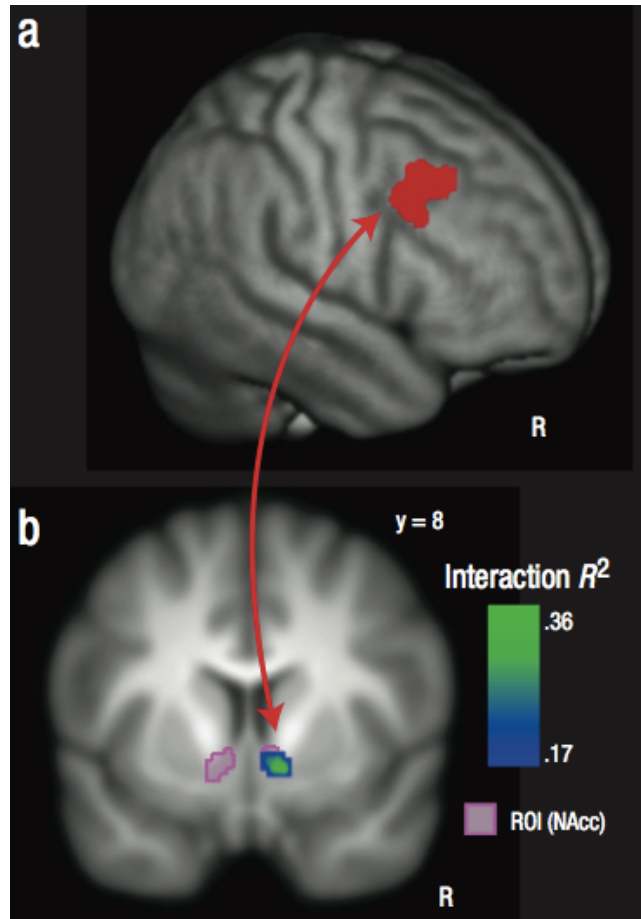
R Nucleus Accumbens

Weng *et al*., 2013
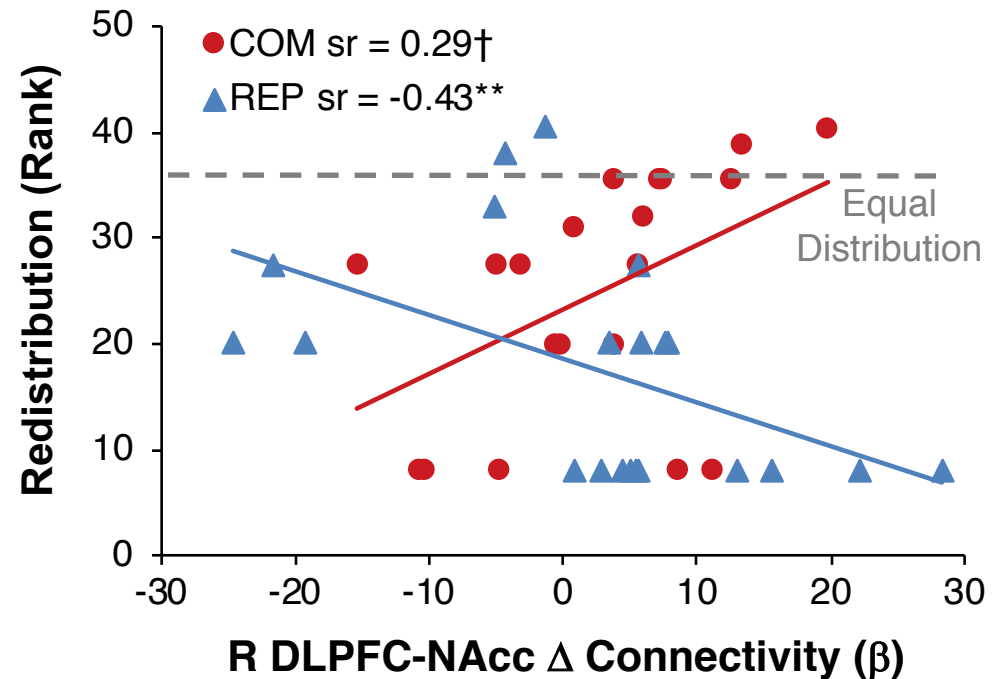
Can compassion become embodied?
Visual attention to suffering

Internal

External

Meditation practices

→

Micro Behaviors:
Visual behavior

Visual imagery and visual perception recruit largely overlapping brain regions
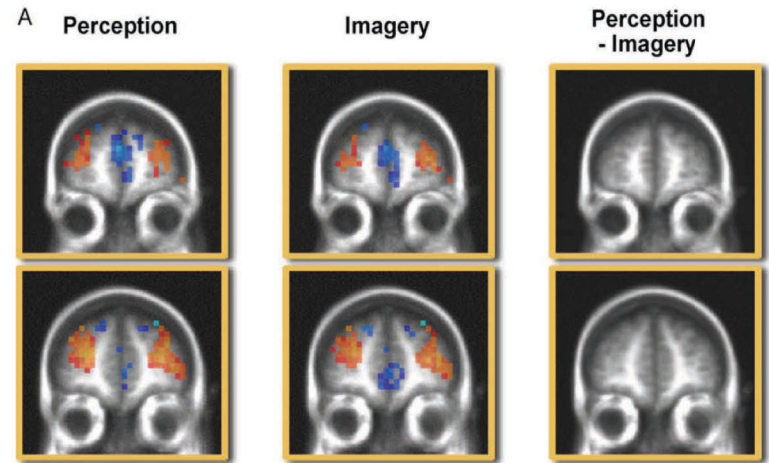
Ganis, Thompson & Kosslyn, 2004

Measuring changes in visual behavior from compassion meditation

A Suffering (Negative)   Non-Suffering (Neutral)
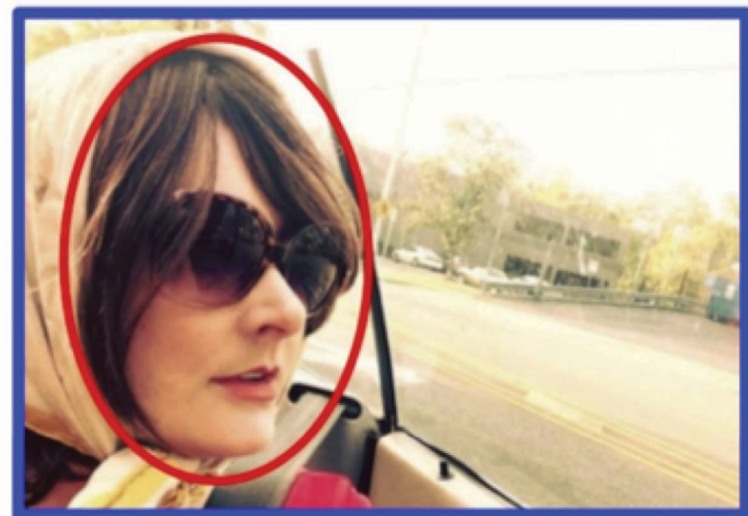
B Looking Time (%) $= \dfrac{\bigcirc\ \text{\# data points in AOIs}}{\square\ \text{\# data points in screen}} * 100$

Compassion meditation cultivates more balanced emotional responses in the face of suffering

Weng, Lapate, Stodola, Rogers & Davidson, *Front Psychol* 2018
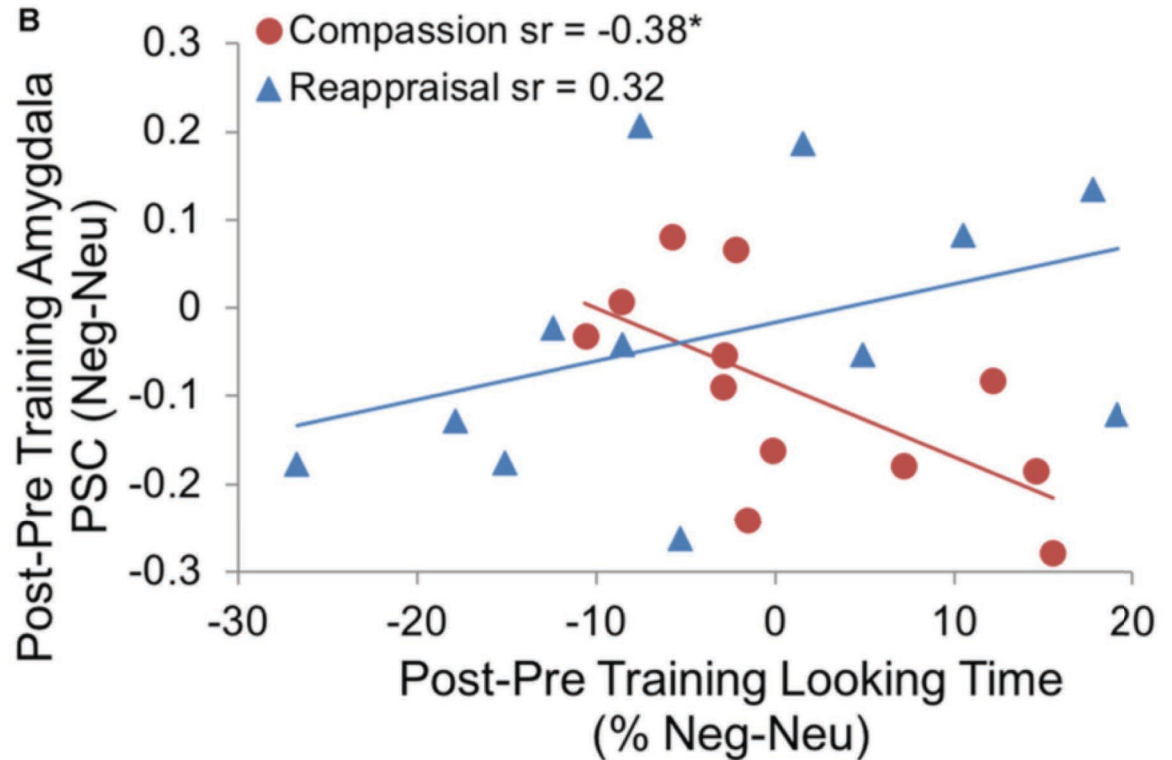
CAN COMPASSION BE LEARNED?

Free meditation download

Try It and Share It!

> 18,000 downloads!

http://centerhealthyminds.org/well-being-tools/compassion-training/

Summary and Discussion

- Compassion training increased altruistic redistribution, demonstrating that social behavior can be changed with just 2 weeks (7 hours) of daily mental training

- Greater redistribution after COM is associated with changes in the neural responses to human suffering in systems involved in

  - Understanding the suffering of others
  - Executive control and emotion regulation
  - Social reward and charitable giving
  - Decreased distress/arousal (with greater visual attention)

Empathy and Compassion are distinct

- Participants learned empathy training THEN compassion
- Empathy = "feeling with", ↑ negative affect, sharing pain
- Compassion = caring and concern, ↑ positive affect, reward

Insula
amPFC

● Δ1 Emp HE >
Δ1 Mem HE

● Δ2 Comp HE >
Δ2 Mem HE

Overlaps with empathy
meta-analysis

Ventral
Striatum

Klimecki, Leiberg, Ricard
& Singer, *SCAN* (2014)

Break the Cycle
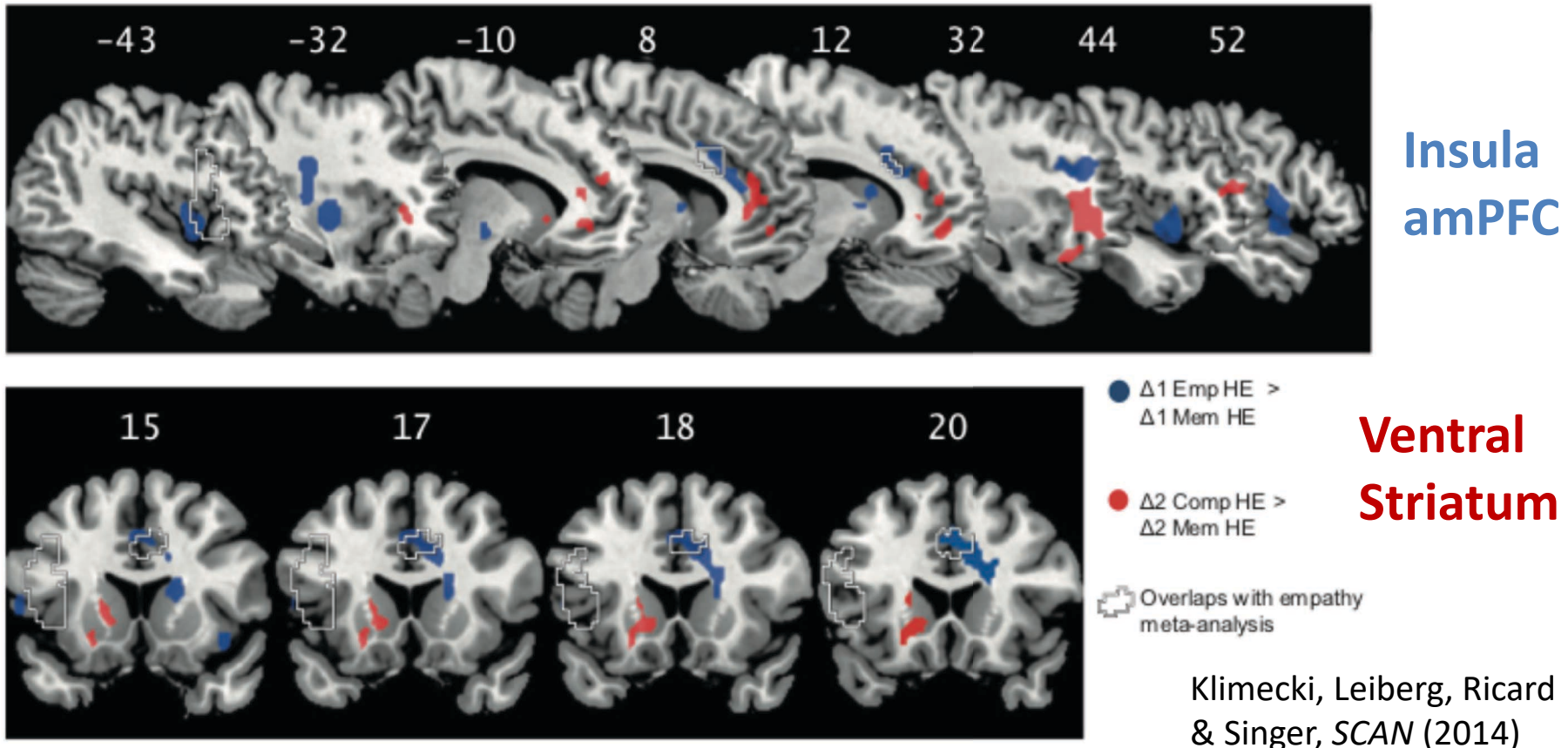
Something Happens

Outer Life

Familial
Intergenerational
Cultural & Historical

With Kind Awareness:
Response

Choose a better way

We Feel and Think some things
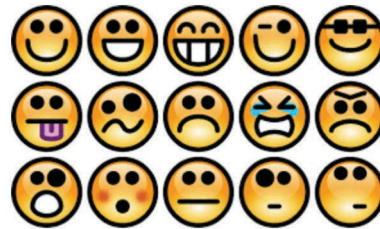
Inner Life
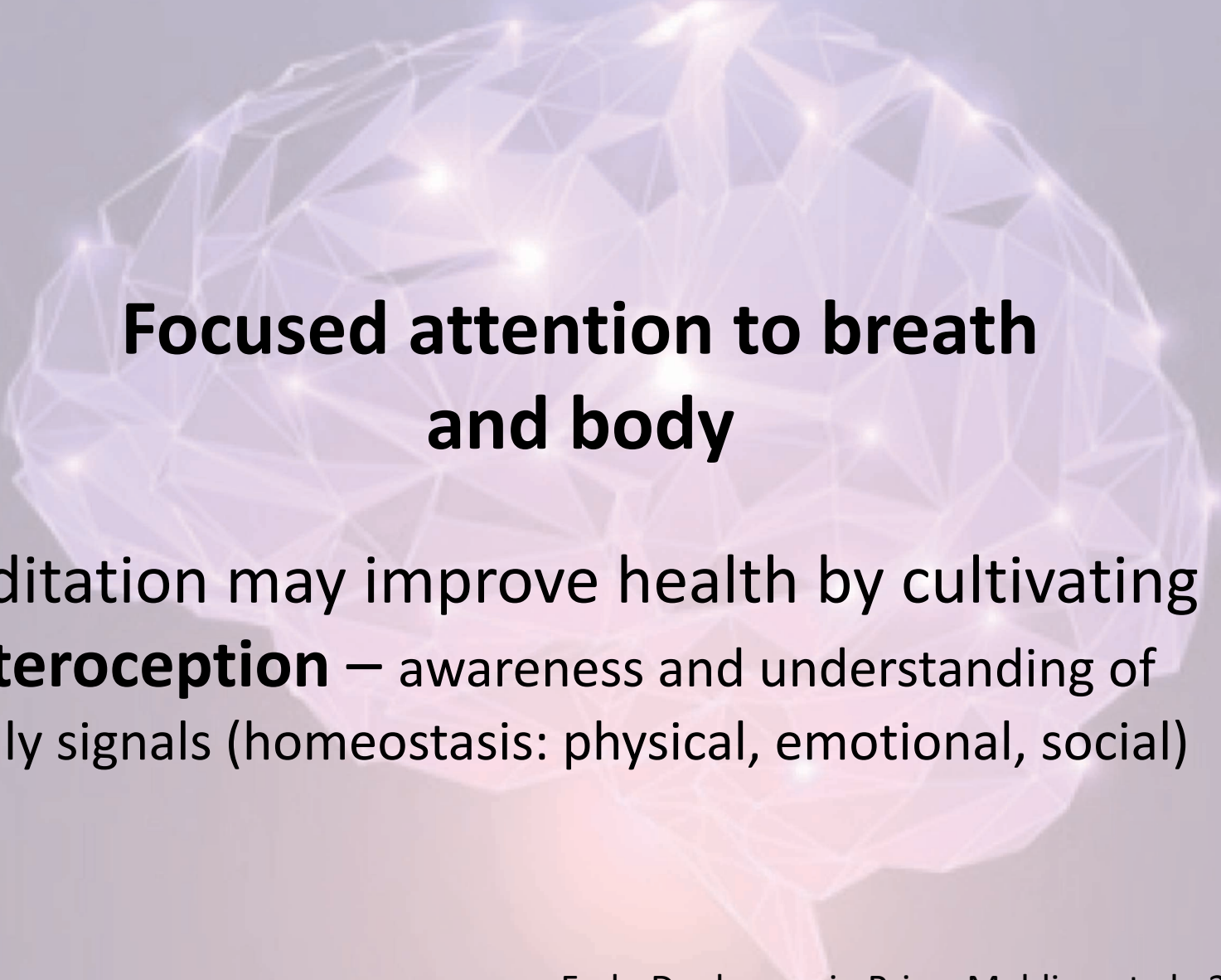
We Do Something

Eat
Drink
Drugs
Sleep
Yell
Shut Down

Without Awareness:
Reaction, Habit, Autopilot

Slow it down
Bring kindness
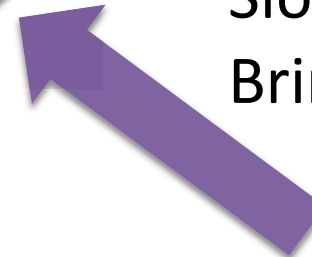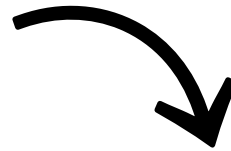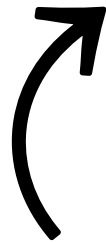
Focused attention to breath and body

Meditation may improve health by cultivating **interoception** – awareness and understanding of bodily signals (homeostasis: physical, emotional, social)

Farb, Daubenmeir, Price, Mehling et al., 2015

The body gives us signals about the state of our internal and external environment

Interpretation

Sapolsky; LeDoux; Feldman-Barrett; Greenberg
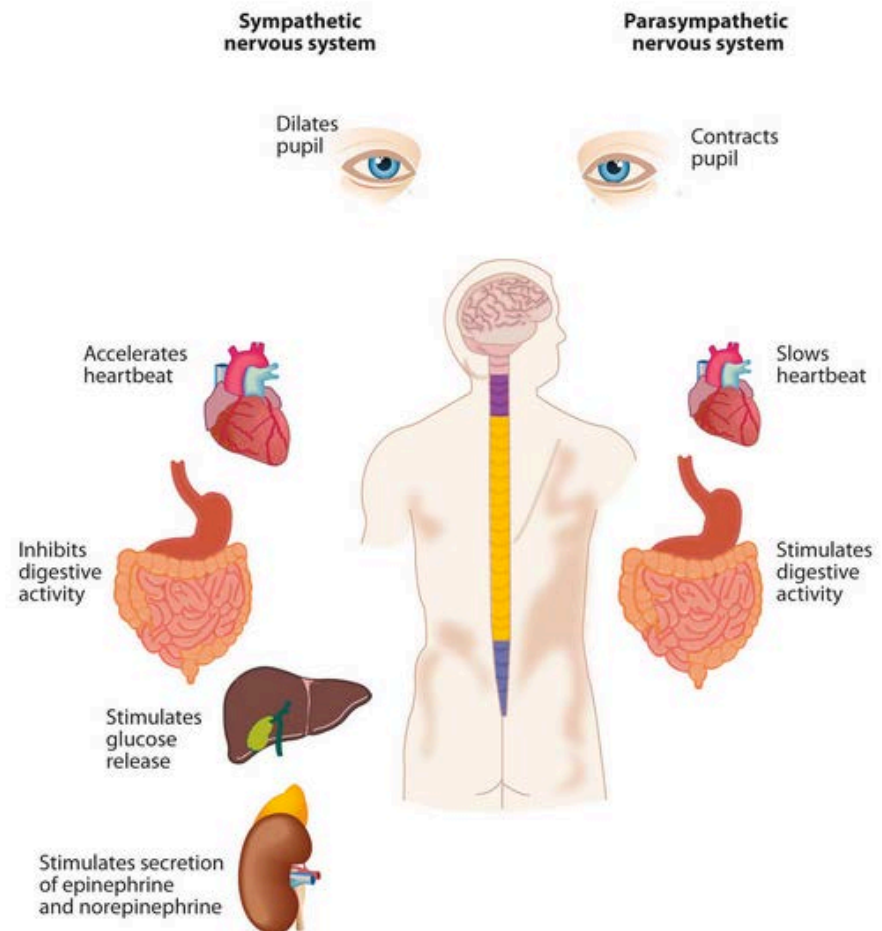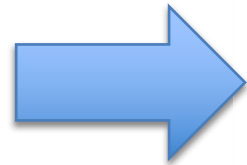
Emotional awareness through body awareness

Emotions rated as colors in the body

Clinical Experience

Nummenmaa et al, *PNAS* 2014
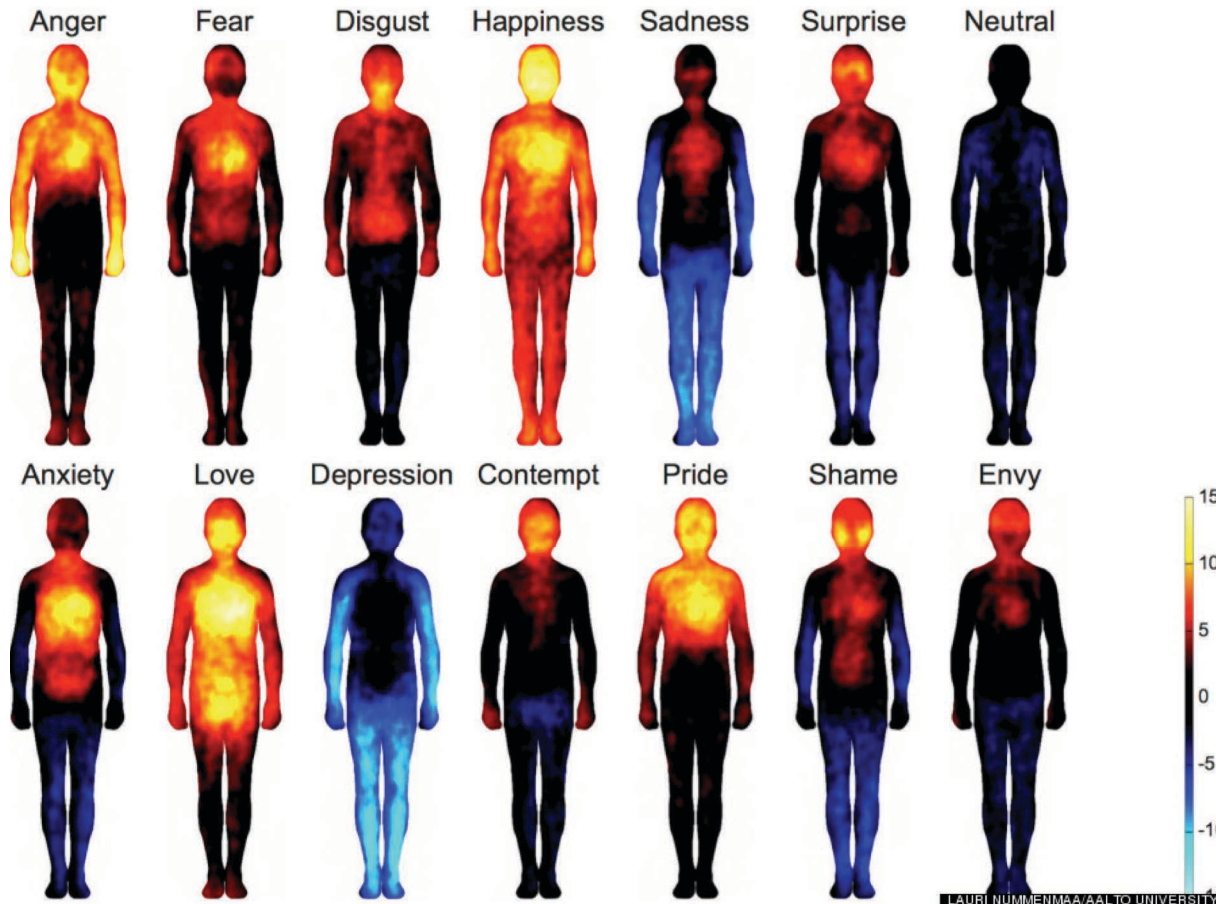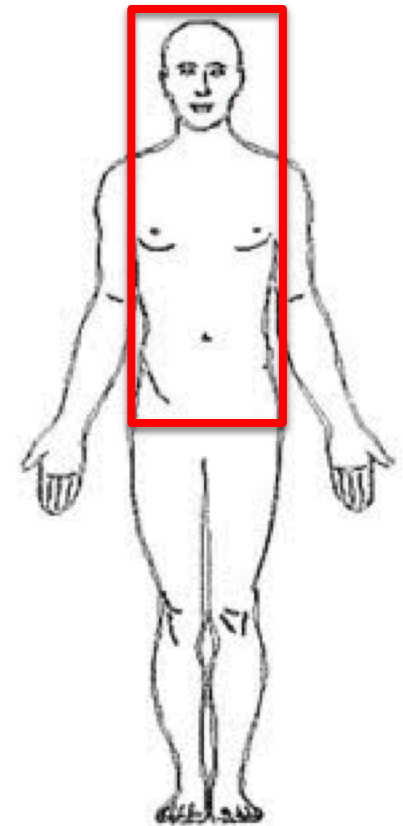
Paying attention is related to happiness; mind wandering can be related to unhappiness
(Killingsworth & Gilbert, 2010)

- Text message assessment
  - 250k data in 5000 ppl
  - Activity, mind wandering, feeling
- 47% of data indicated mind wandering (↑ MW = ↑bubble)
- People less happy when MW
- Meditation helps recognize MW and re-focusing attention
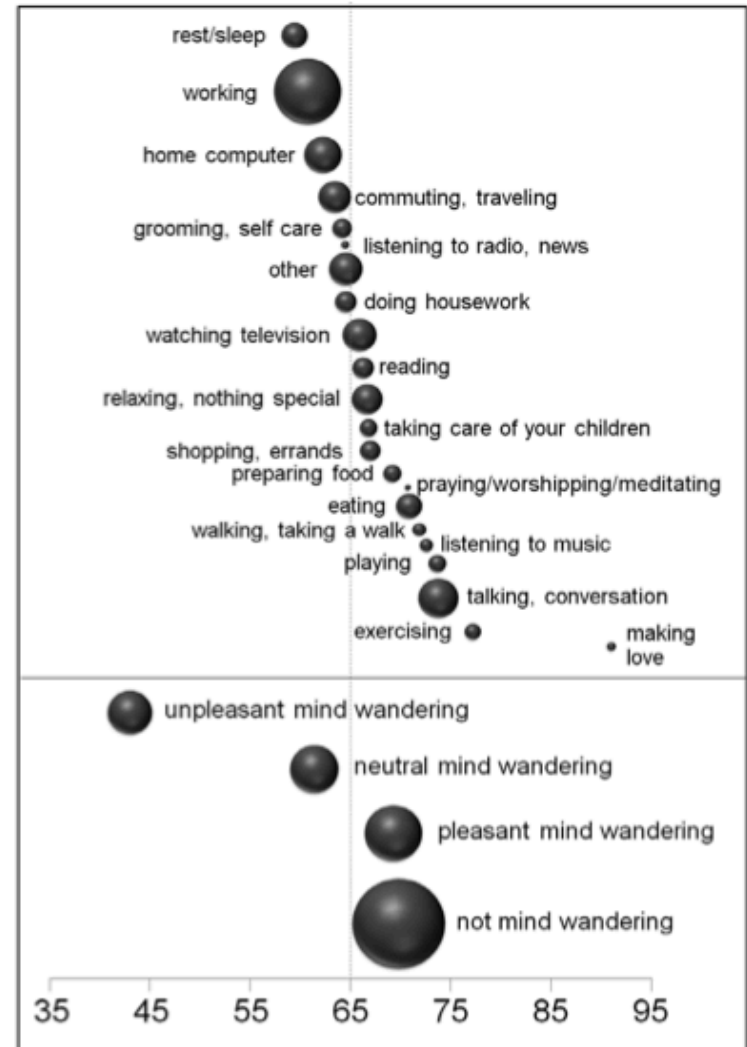
Mean happiness

Breath and body meditation: Practice

Breath
Other part of body – back, shoulders, hands
Emotions are in the body – face, heart, stomach, lungs

Measurement issue in meditation:

Mental states are diverse and fluctuating
but standard neuroscientific methods average them together

Breath

Meditation Period

Dinner

Breath

Sleepy

World Peace

Time
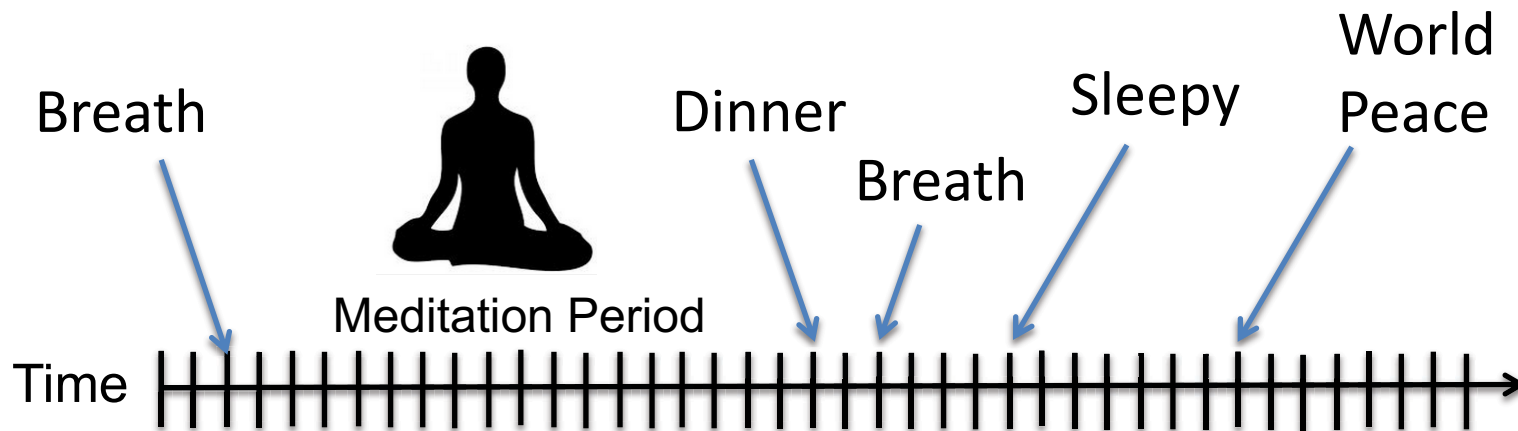
fMRI: picture every 2s

Brain activity is **averaged** within each person and across people

Averaged group brain
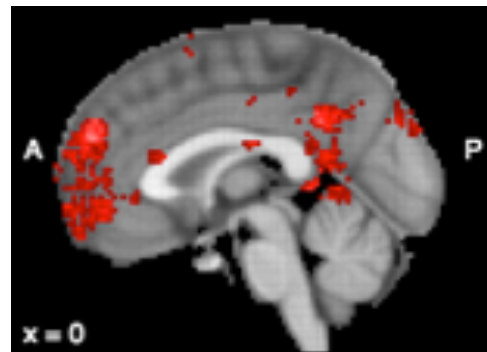
Why does this meditation help with stress?

- Stressful thoughts: Runaway train

Something bad happened	→	I'm not doing well in my life	→	More bad things will happen

Past -> Depression   Self-Criticism   Future -> Anxiety

Negative Thought Loop

Meditation can interrupt the runaway train

- Focus on present-moment feelings in the body, bring nonjudgment/kindness

- Meditation activates "experiential mode" and quiets "narrative mode"

- Self-knowledge – what is my body telling me?

After 8 weeks of Mindfulness-Based Stress Reduction
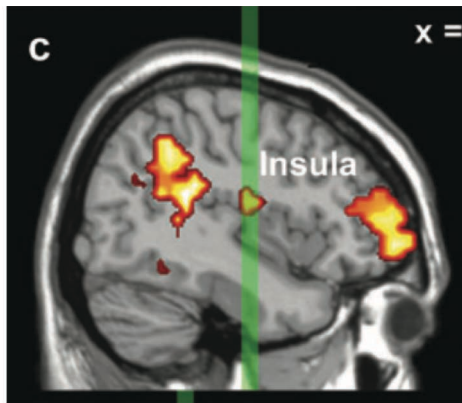
Experiential Mode
Insula - Interoception
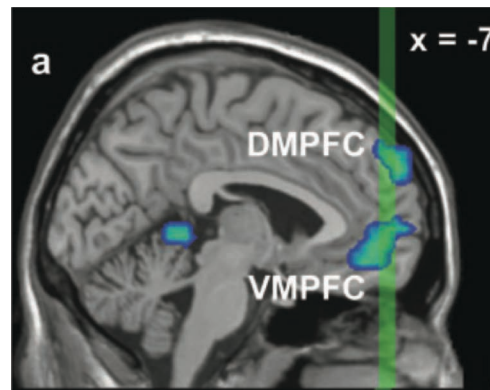
Narrative Mode
Default Mode Network

Farb et al., SCAN 2007

Default Mode Network:
Mind wandering and self-referential processing

Buckner et al.: The Brain's Default Network

AUTOBIOGRAPHICAL MEMORY
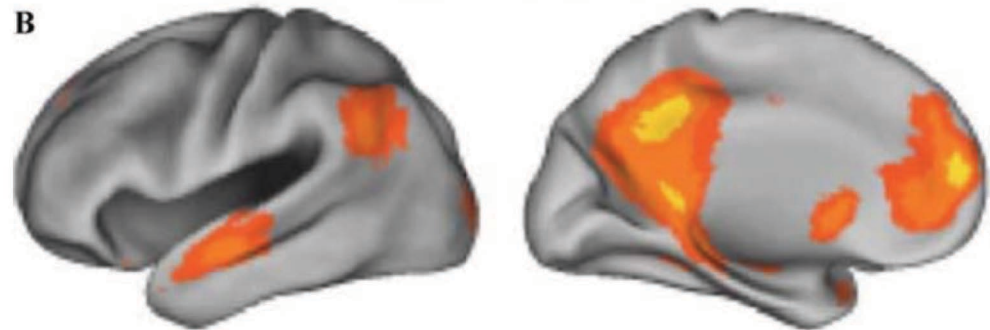
- Self-referential processing (Buckner, Gusnard)
    - Autobiographical memory retrieval
    - Envisioning the future
    - Thinking of others' minds
- Self-relevant simulations
- Self-generated thought (Andrews-Hanna)

ENVISIONING THE FUTURE

Buckner, Andrews-Hanna & Schachter, *ANYAS* (2008)

Mental states change during meditation over time (temporal analysis)

Button Press:
Mind Wandering

Executive:
Prefrontal Cortex

Default Network:
mPFC & PCC

Meta-Awareness:
Insula

Executive:
PFC & parietal

Time

1. Sustained Attention

2. Mind Wandering

3. Conscious Awareness

4. Shifting Attention

Hasenkamp et al., *NeuroImage* (2012)
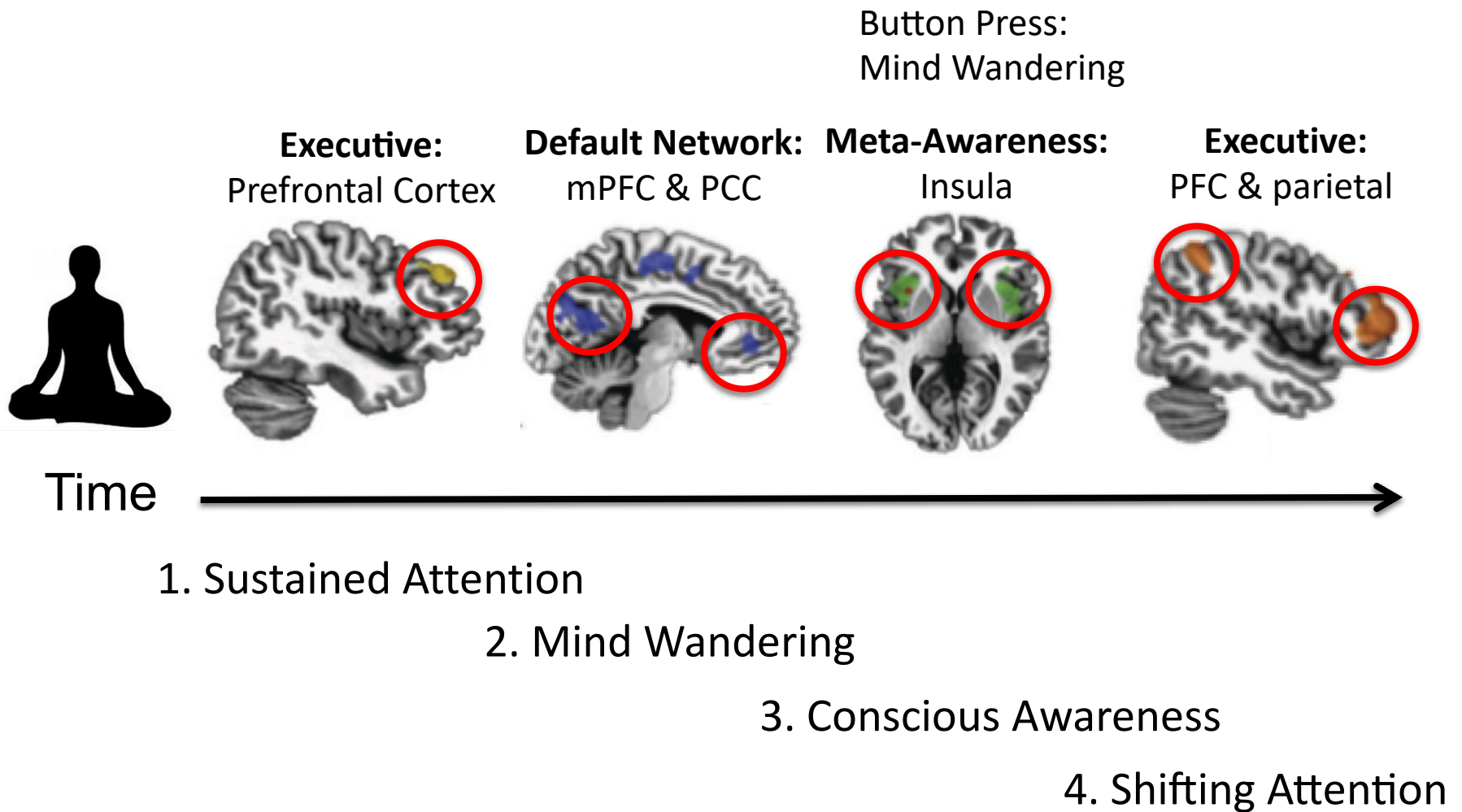
Interrupting the runaway train

- Where are you headed?

- Slow down the train (become the conductor)

- Get off at the next stop (meditation gives you more stops)

- What train do you want to get on?

Individual: Thoughts, Feelings, and Behaviors

Different therapies
target different aspects
of the triad to alter loops

Mindfulness and Compassion
Meditation

Cognitive-Behavioral Therapy

THOUGHTS
What we think affects
how we feel and act

T

E

B
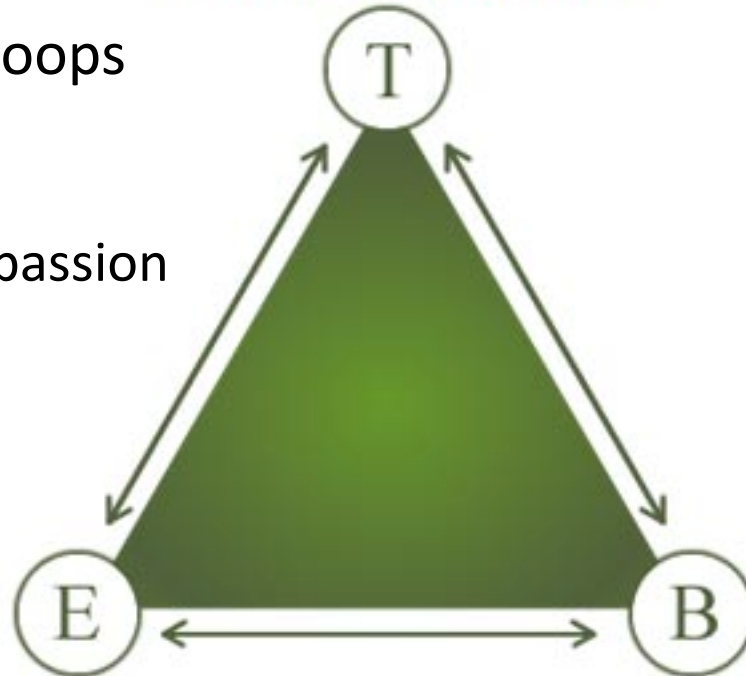
EMOTIONS
How we feel affects
what we think and do

BEHAVIOUR
What we do affects
how we think and feel

Emotion-Focused Therapy

Behavioral Activation Therapy

Meta-analysis: averages brain activity across studies (N=25)

Fox, Dixon et al., *Neuro & Biobeh Rev* 2016
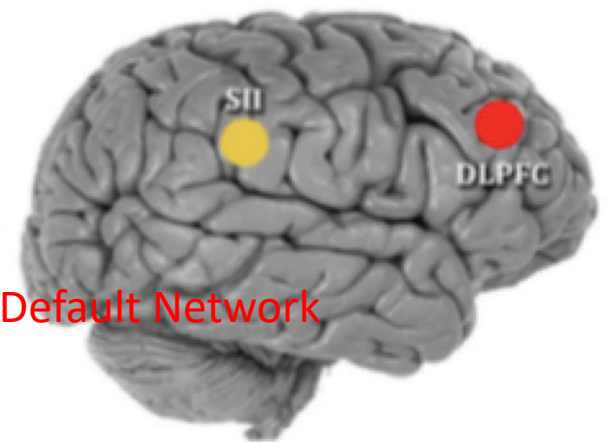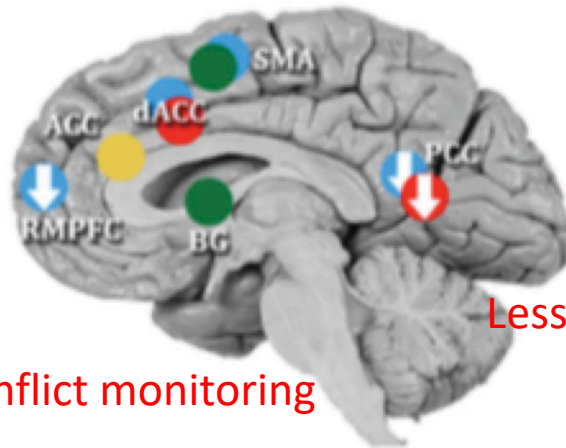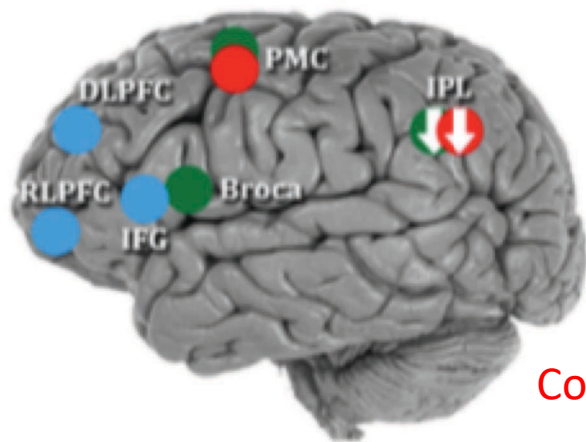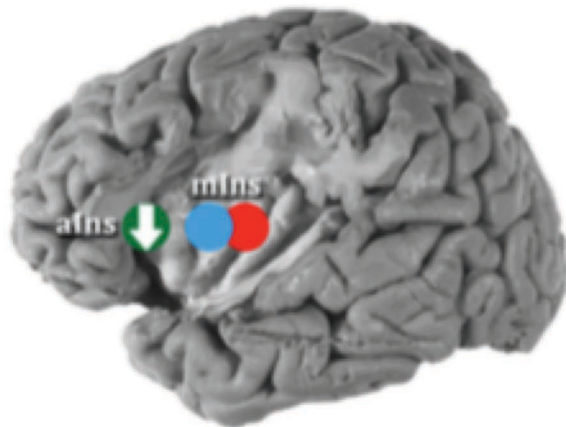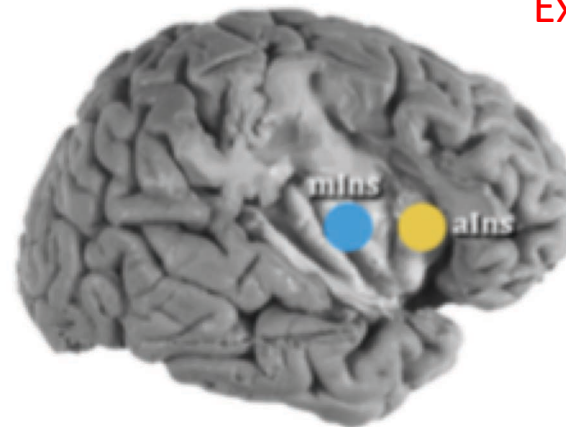
Spatial averaging:
Each person's brain mathematically warped to fit a standardized brain – **"Normalization"**

Meditator 1

Control 1

"standard"
MNI152 brain
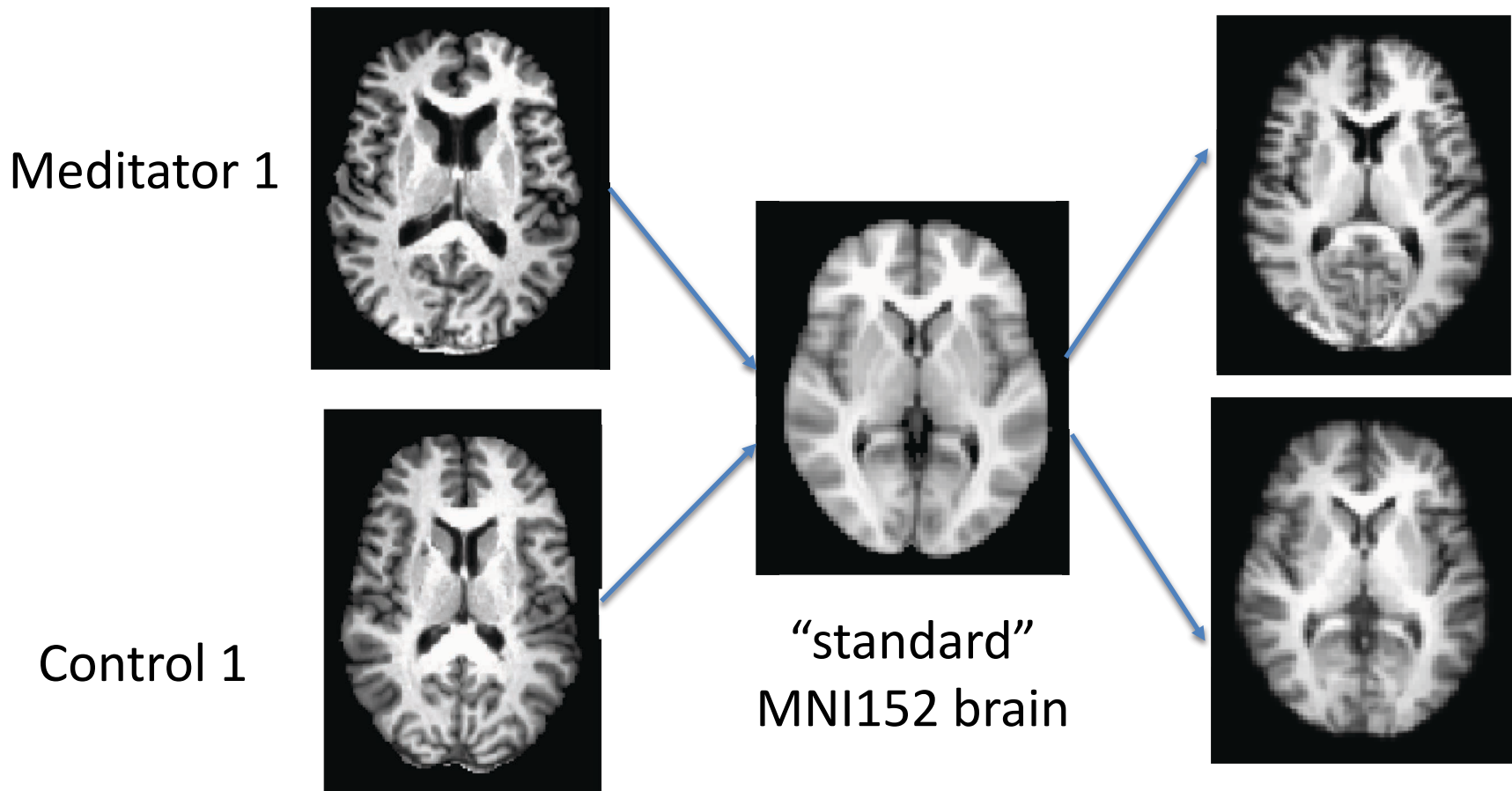
Assumption: Activity in the same regions across different people serve the same function

Measurement issue in meditation:

Mental states are internal, diverse, and fluctuating

Breath

Meditation Period

Dinner

Breath

Sleepy

World Peace

Time
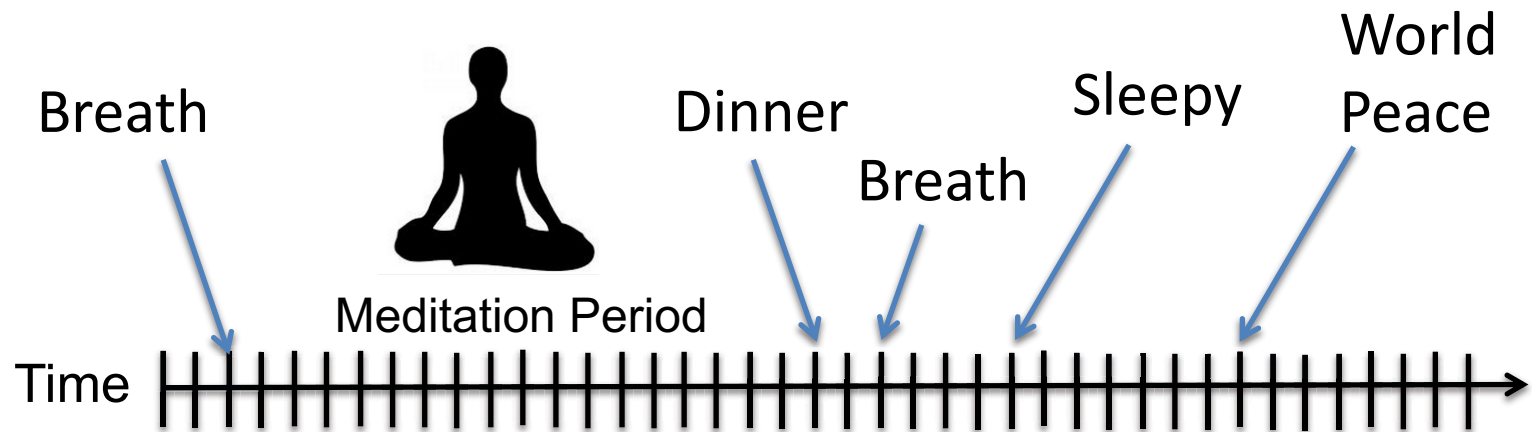
fMRI: picture every 1-2s
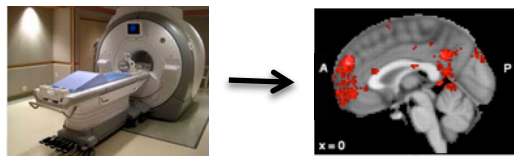
Standard univariate fMRI: average spatial and temporal info into one standardized image
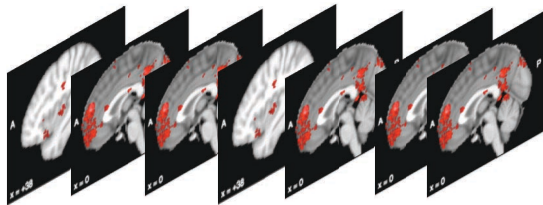
Multivariate fMRI using machine learning:
Preserve and utilize individualized spatial and temporal info

Brain activity is unique like fingerprints

Pattern recognition or machine learning applied to brain data
Multi-voxel pattern analysis (MVPA), Haxby et al., 2001, Norman et al., 2006; Finn et al., 2015

The EMBODY Task:
Evaluating **M**ultivariate Maps of **BODY** Awareness

- Objectively measures meditation practice by applying machine learning (MVPA) to fMRI data
    - Individualized brain activity (conserves spatial info)
    - Track fluctuating object of attention continuously during meditation (conserves temporal info)

Weng, Lewis-Peacock, Hecht *et al.* (submitted)

Machine learning well-established in cognitive neuroscience

Vision: Faces vs. Objects,
Haxby et al., 2001

Short vs. long-term memory,
Lewis-Peacock & Postle, 2008

Social vs. physical pain
Woo et al., 2015

Mindfulness and Meditation Practices: Multi-faceted nature of attention
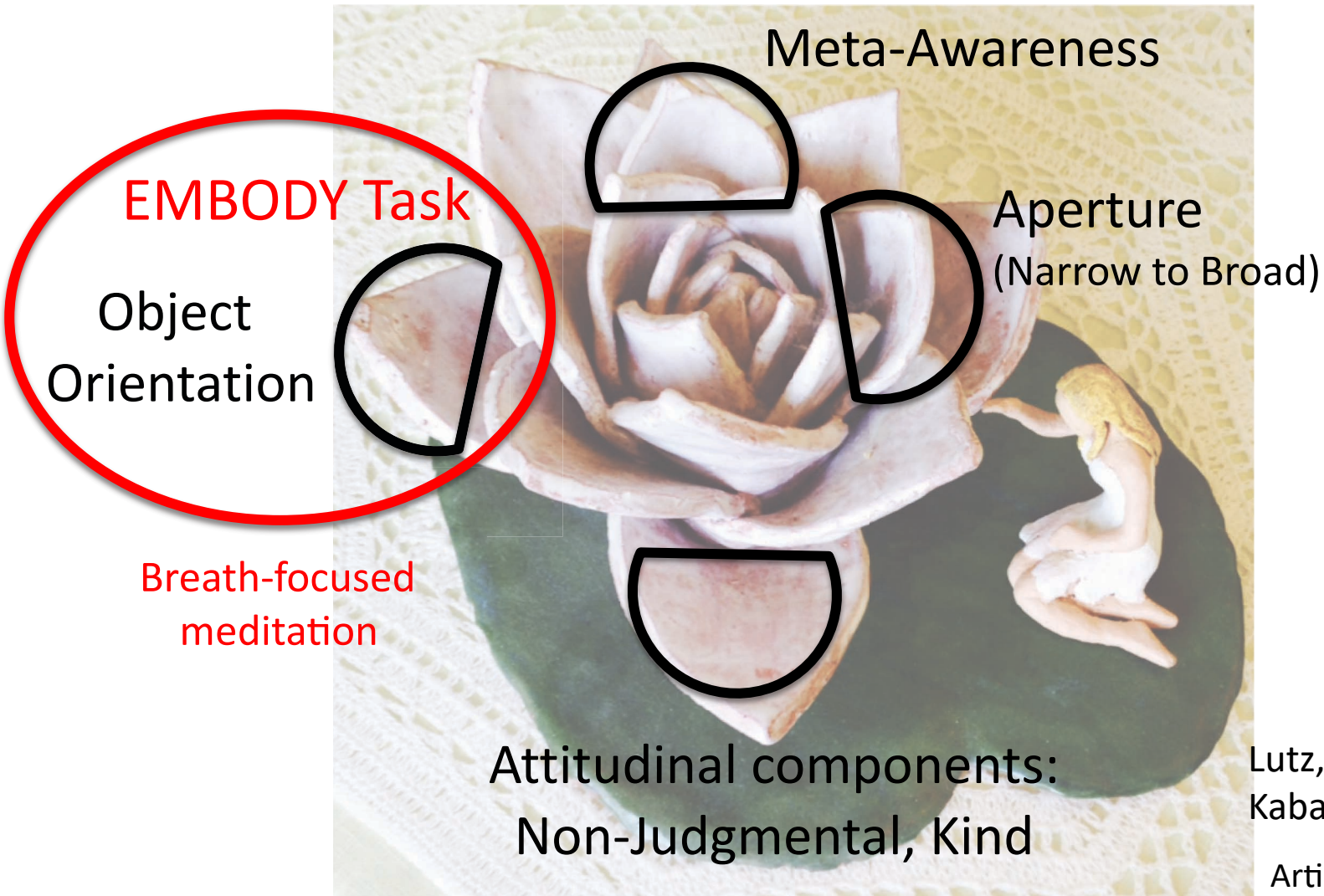
Meta-Awareness

EMBODY Task

Object Orientation

Aperture
(Narrow to Broad)

Breath-focused meditation

Attitudinal components:
Non-Judgmental, Kind

Lutz, Jha, et *al.*, 2015
Kabat-Zinn *et al*.

Artist: Weng, 1997

EMBODY framework: Applying pattern recognition or machine learning to brain patterns during meditation: unique "Brainprints"
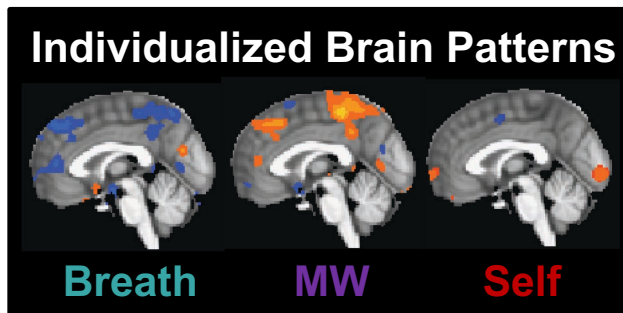

Pattern Recognition
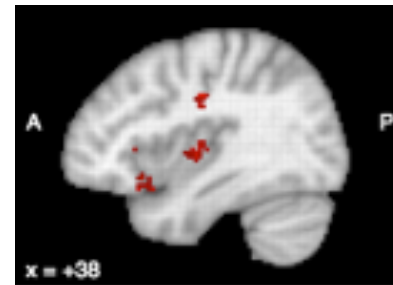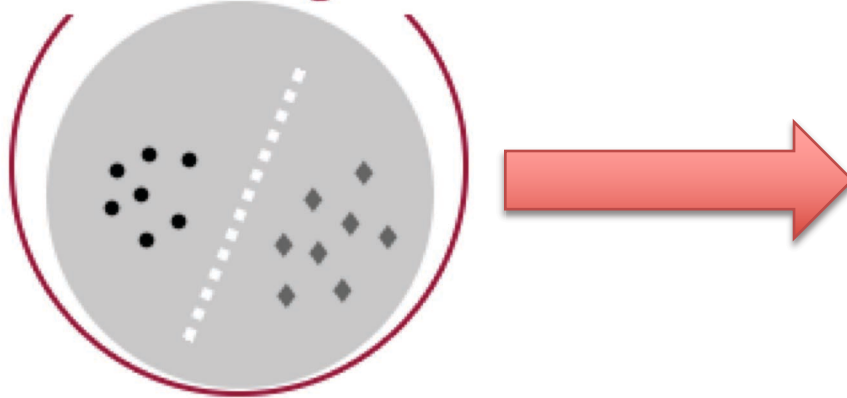
Interoception

Mind Wandering

Classifier-derived decision boundary (d)

Input Classification Decision

f(v)

Feature space

TRENDS in Cognitive Science
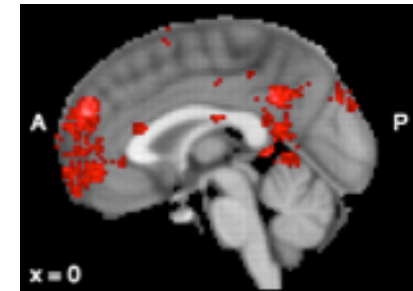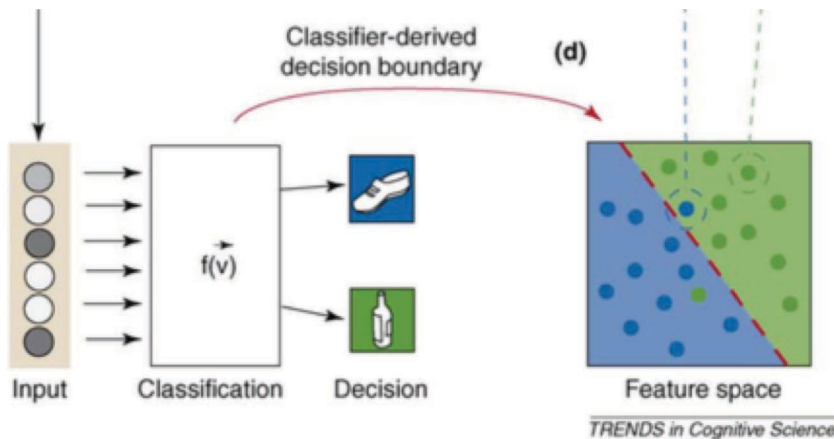
Brainprints - Individualized to each person
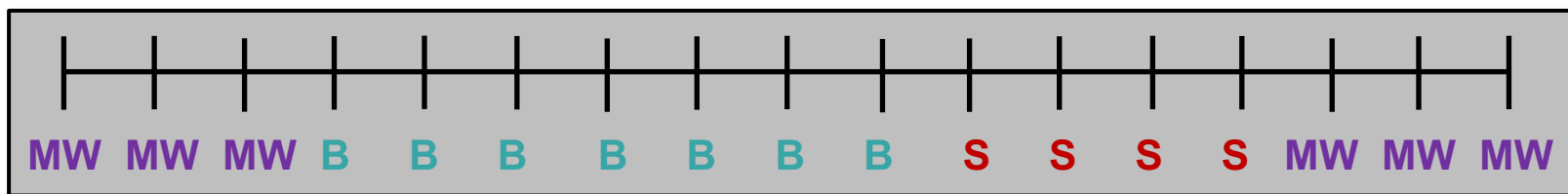Used to read the mind during meditation

EMBODY Framework

Individualized Brain Patterns

Breath   MW   Self

Step 1:
Classifier Training
of Internal Attention

Step 2:
Meditation decoded
by Step 1

Step 1:
Classifier Training
of Internal Attention

IA   IA   IA

Meditation
(600 s)

IA   IA   IA
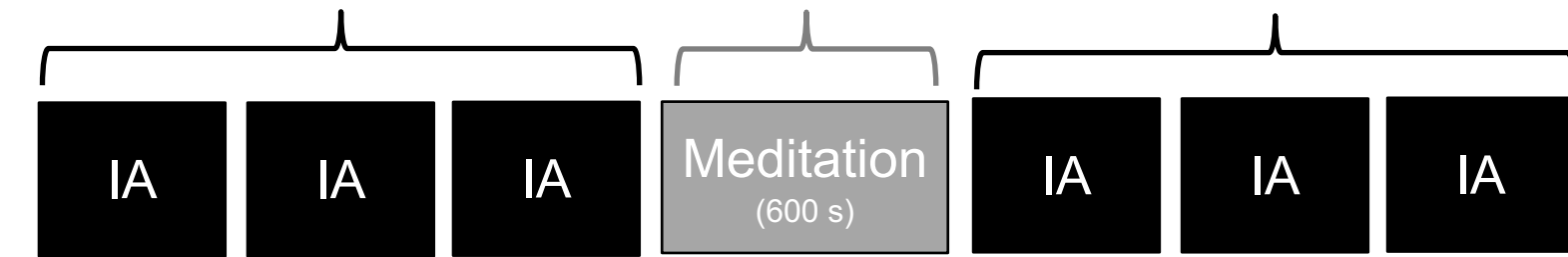
Read-out of meditative mental states

MW MW MW B B B B B B B S S S S MW MW MW

Step 3: Quantification of internal attention during meditation
(percentage time, number of events, mean duration)

Weng, Lewis-Peacock *et al.,* (under review)

Participants

- Recruited from the Bay Area, CA
- Age: 25-65, no health conditions affecting breathing, no current mental illness or psychiatric medications, MRI-compatible
- Recruited from word of mouth, meditation center flyers and social media, Craigslist
- **Meditators (N=8)**
  - 6 male, 1 female, 1 genderqueer
  - Past 5 years: ≥90 min/week, ≥14 days of silent retreat
  - Vipassana and Zen traditions
    - At least half of practice involves attention to breath and body sensations
- **Novice Controls (N=8)**
  - age- (within 10 years) and gender-matched, no significant mind-body practice
- **Race and ethnicity**
  - 12 White, 1 Hispanic/Latinx, 1 Asian, 2 multiracial/multiethnic

EMBODY Step 1: Internal Attention (IA) task

Classifier training of IA brain patterns

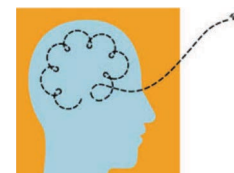Directed auditory instructions (16-52s, eyes closed)
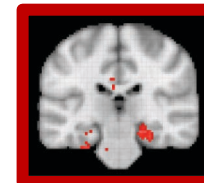
Brainprints

Breath Meditation:

Pay attention to your **breath**
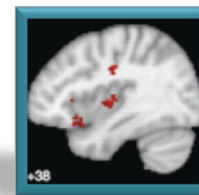
You may **stop** now
(mind wandering)
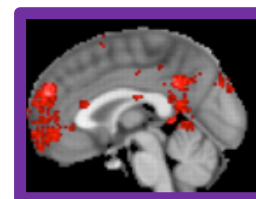
Think about the past week
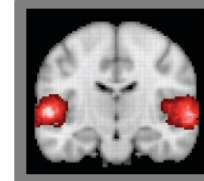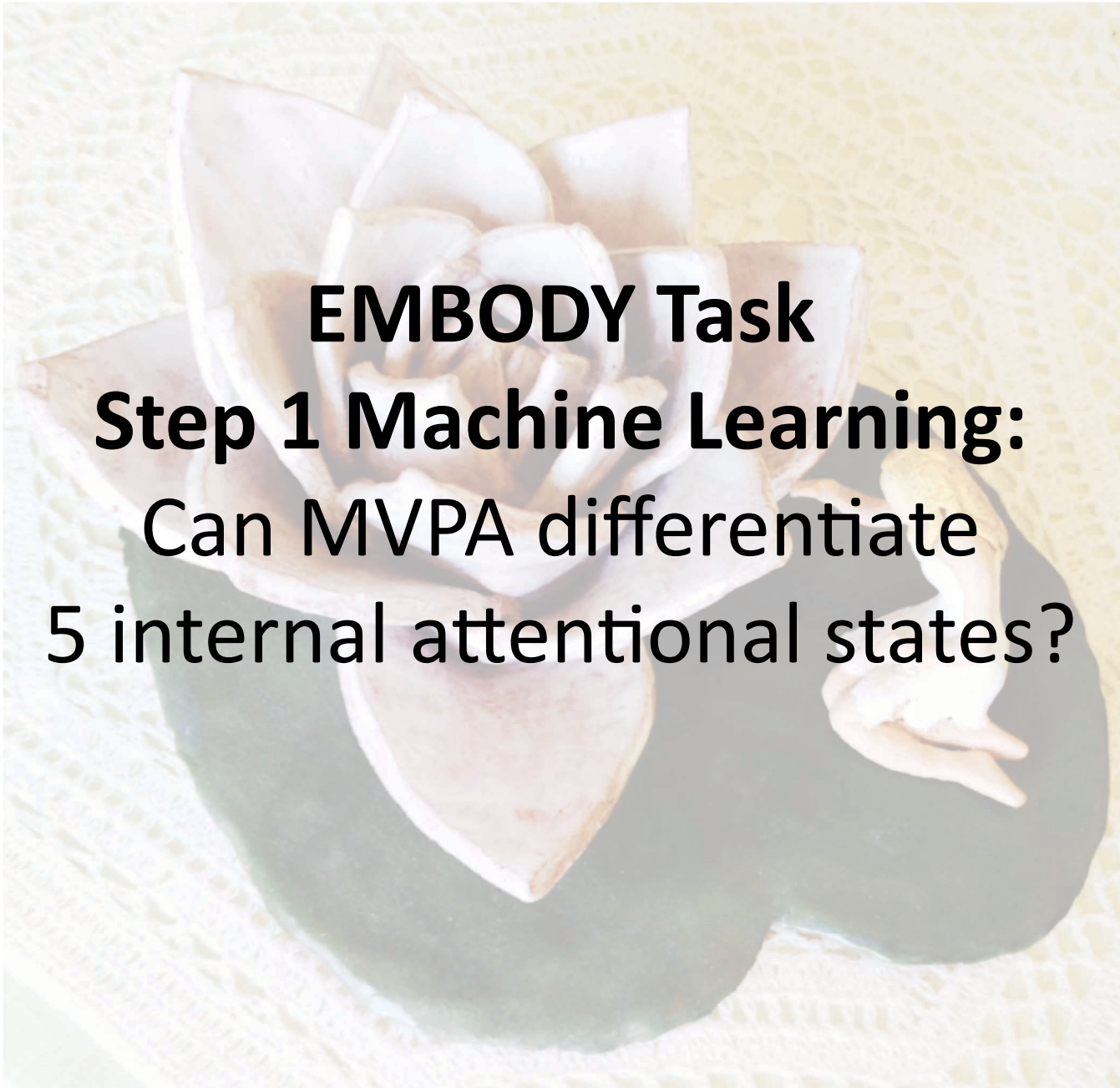**(self-referential processing)**
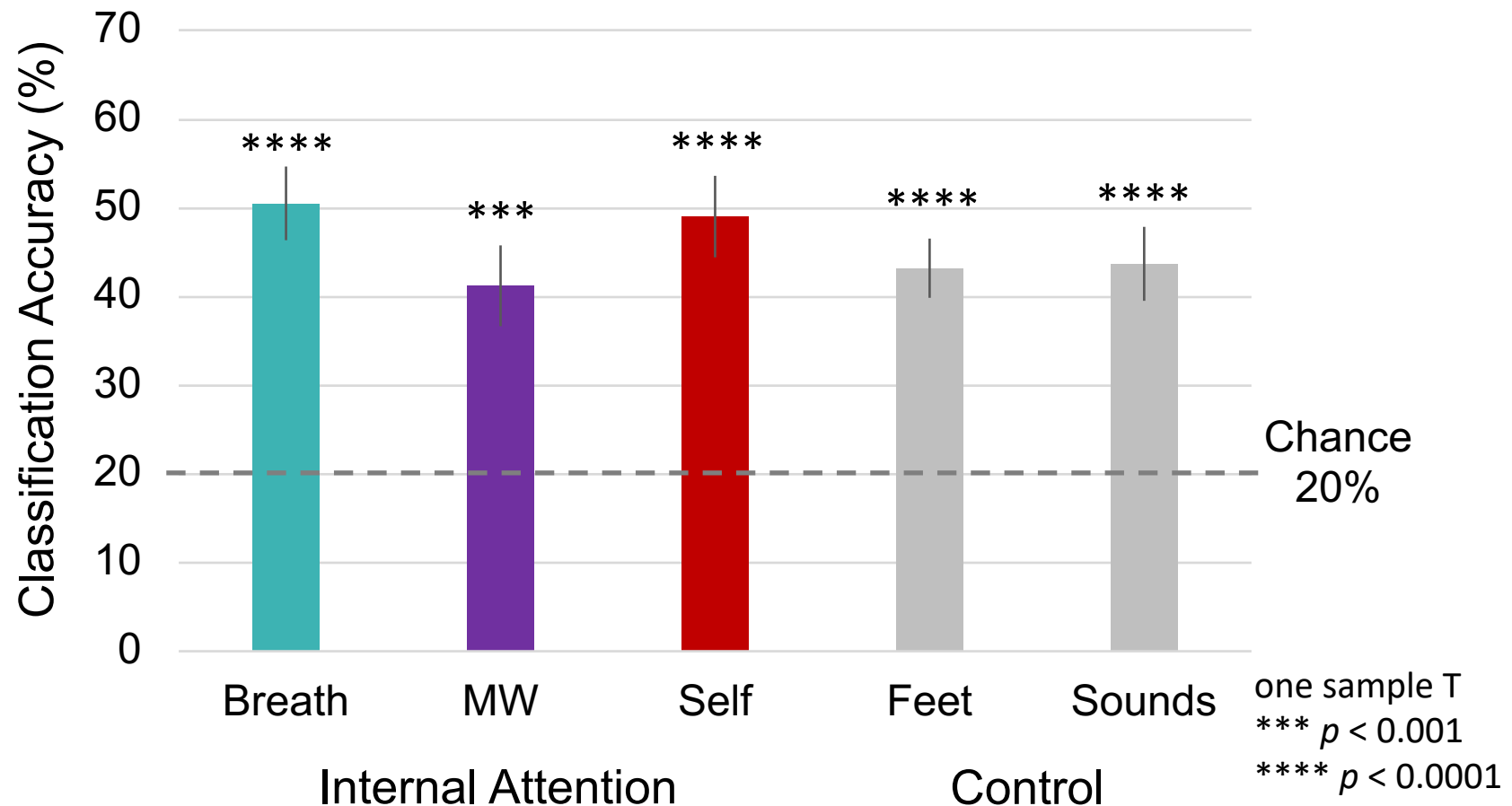
Control:

Pay attention to your **feet**
(control)

Pay attention to the **Sounds**
(control)

EMBODY Task
Step 1 Machine Learning:
Can MVPA differentiate
5 internal attentional states?

Across all participants, the neural pattern for each mental state was distinguished above chance

one sample T
*** $p < 0.001$
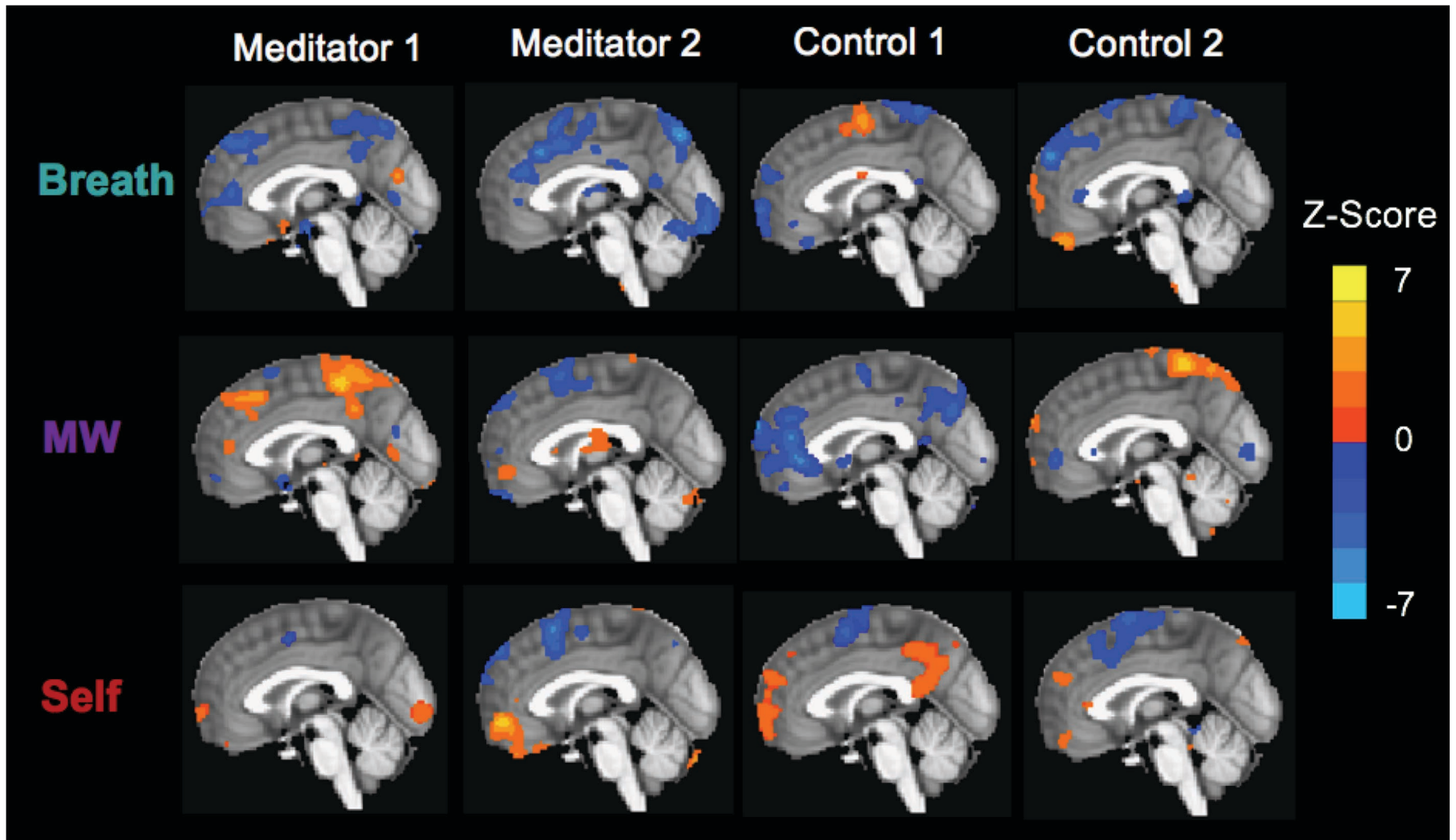**** $p < 0.0001$

Individual-level accuracy:
Meditators: 8/8   Controls: 6/8   **Total: 14/16**

Weng, Lewis-Peacock, Hecht, *et al.,* (under review)

Honoring neural diversity:
Individualized Brain Maps

Voxels that contribute to *discriminability* of neural patterns associated with mental states
McDuff et al., *J Neuro* 2009

EMBODY TASK

Step 2 Machine Learning:

Decoding mental states during meditation
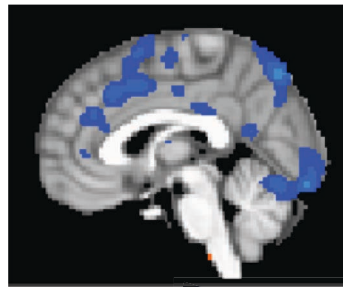
EMBODY Task Step 2:
Decoding the Meditation Period

- **Use individualized brain patterns** from Step 1 to decode object of attention during meditation period
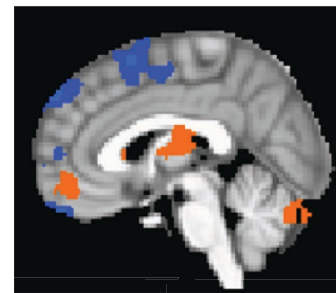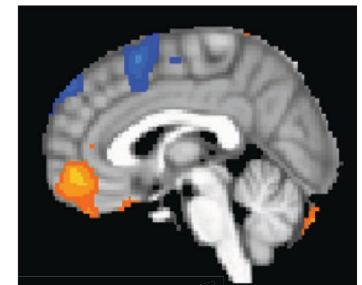

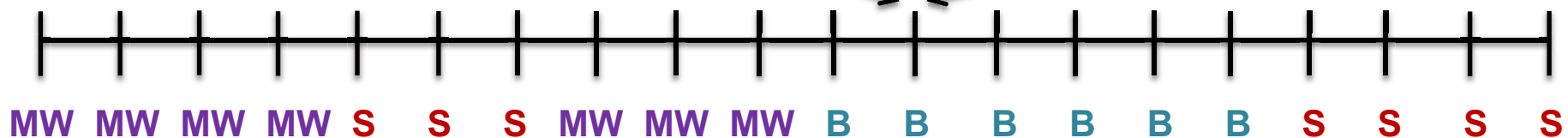**Meditator 1**

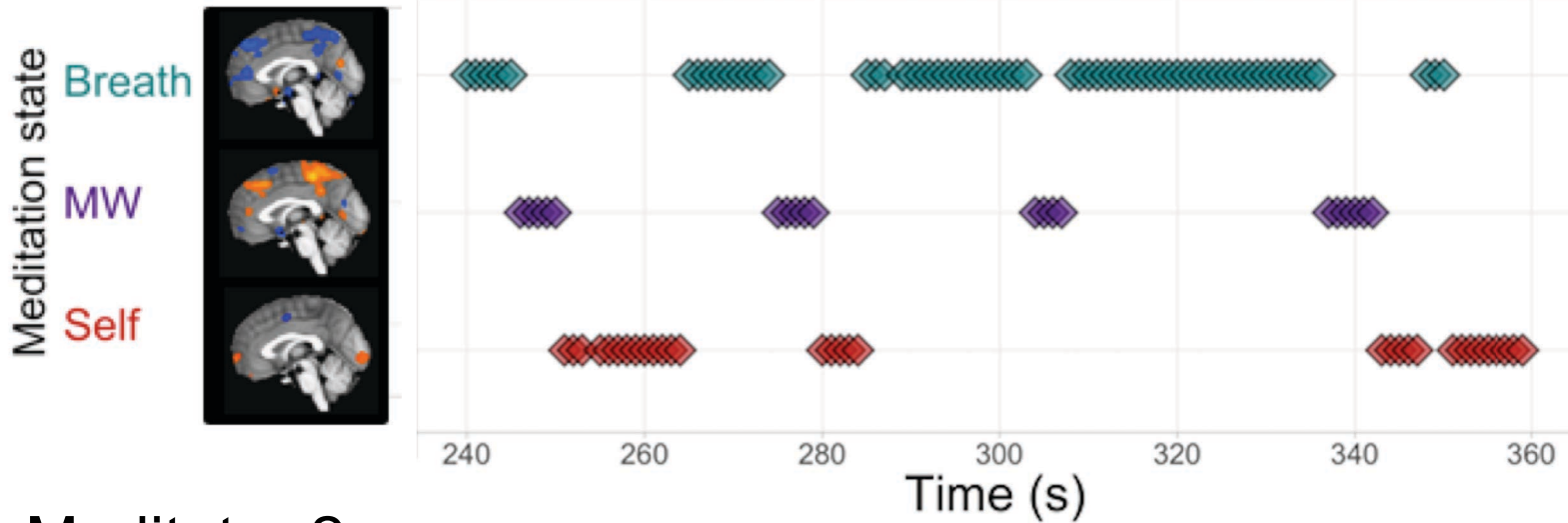**Breath** **Mind Wandering** **Self**
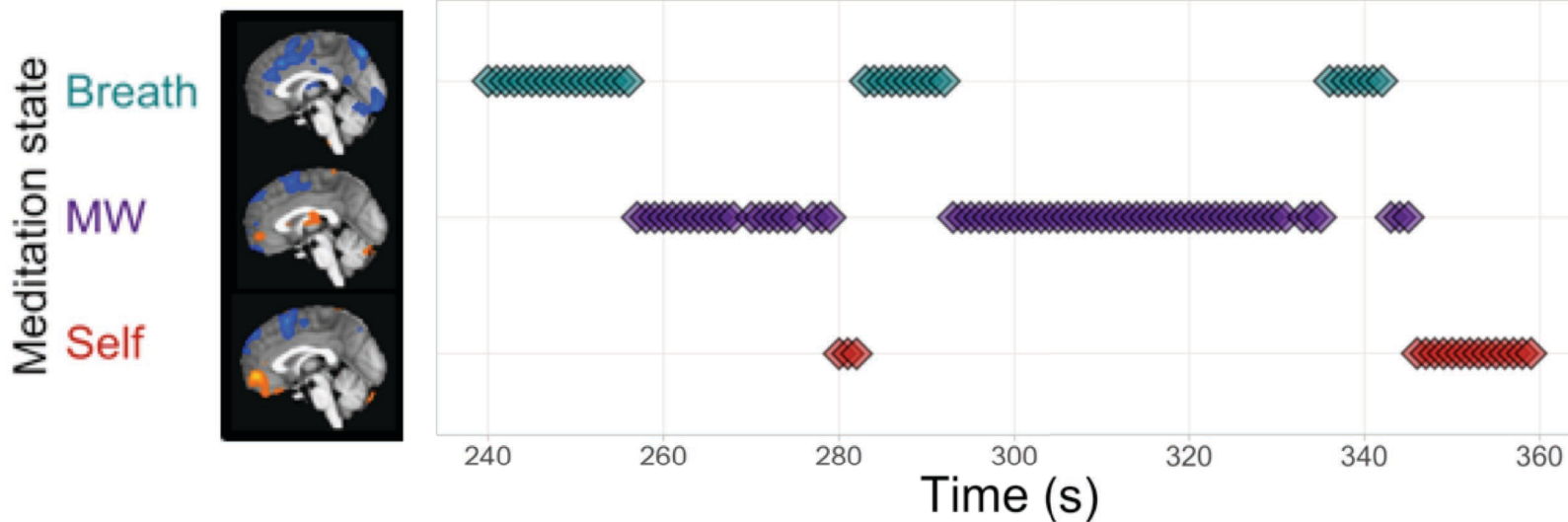
OR OR

Meditation Period
Time Point (600 sec, 10 min)

MW MW MW MW S S S MW MW MW B B B B B B S S S S

Classifier decision at each time point

Individualized Decoding of Meditation Period

Weng *et al.*, (under review)

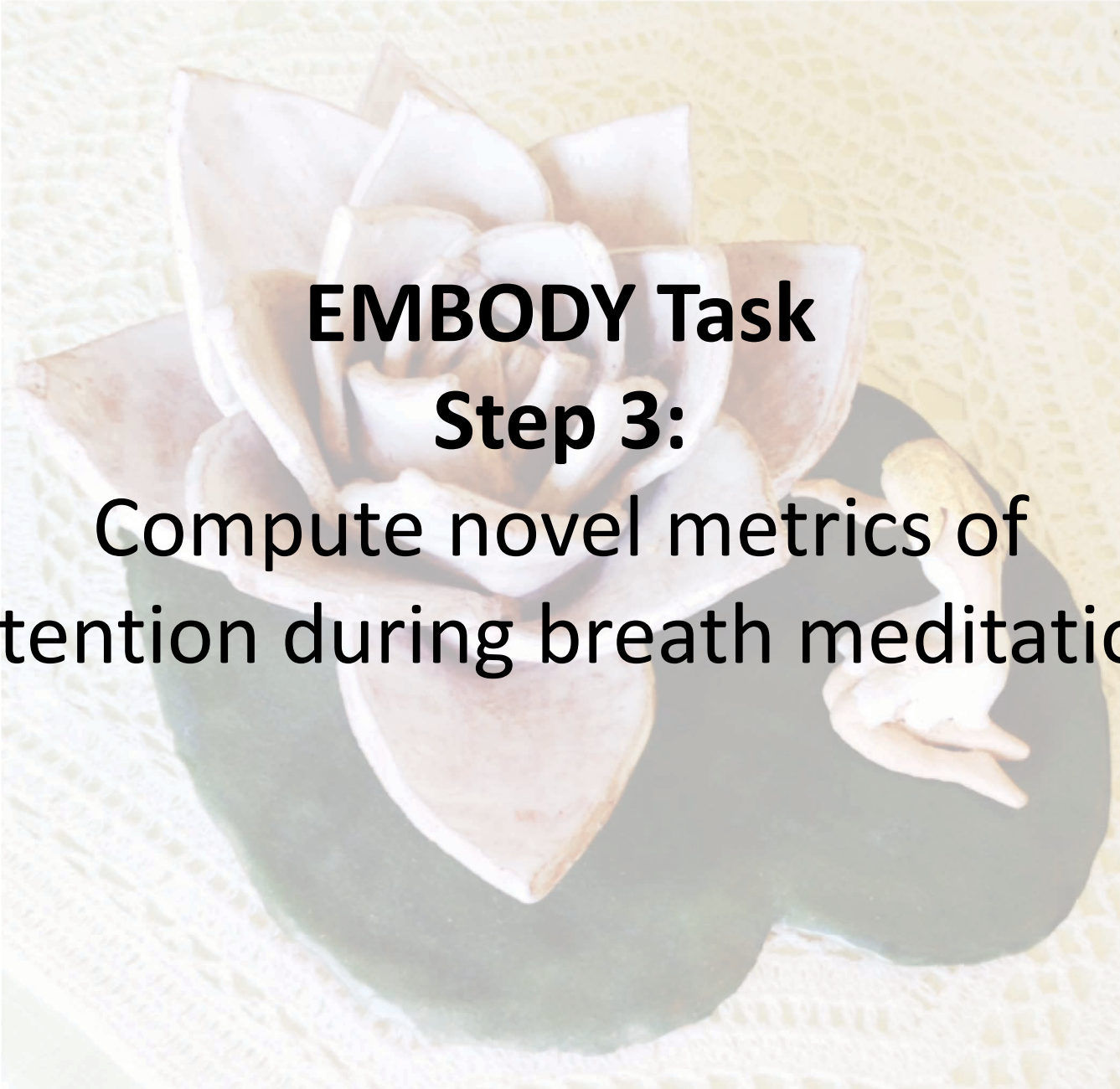# Individualized Decoding of Meditation Period
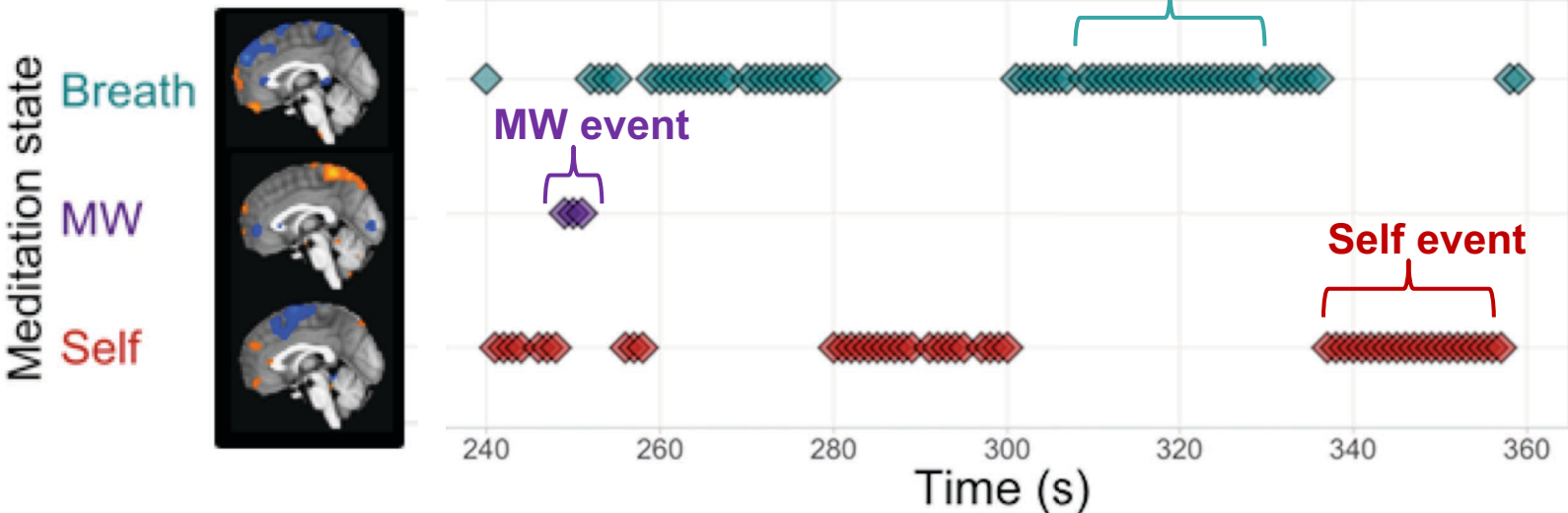
Weng *et al.*, (under review)

EMBODY Task
Step 3:
Compute novel metrics of attention during breath meditation

Step 3: Compute metrics of breath meditation skills

Meditation Period
Time Point (600 TRs)

Self event
(>= 3 contiguous)

Breath event
(>= 3 contiguous)

MW MW B B B MW MW MW MW MW S S S S B B B B S S
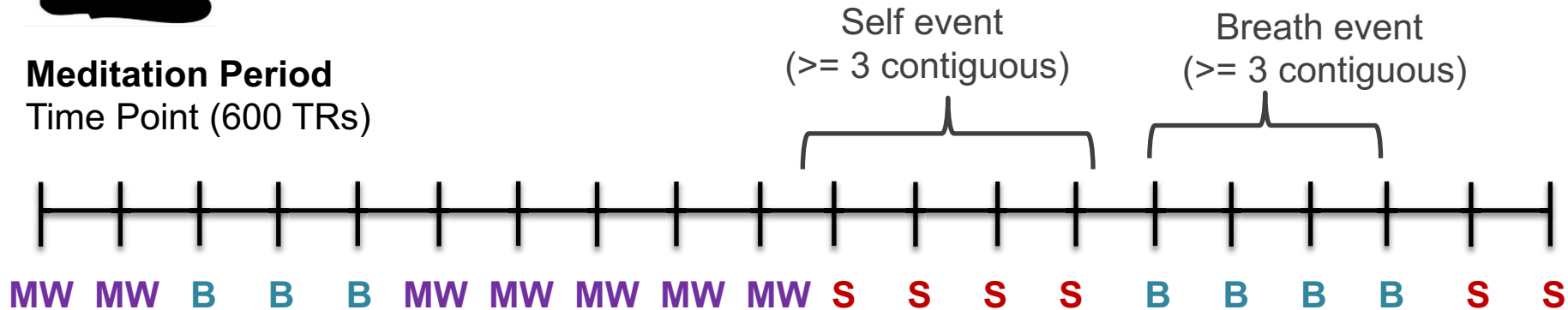
	Count	% Time	Events	Duration (s; SD)
Breath	233	40.1	15	13.4 (8.08)
MW	165	28.5	13	11.0 (12.20)
Self	182	31.3	11	10.75 (3.59)

Attention profiles during meditation
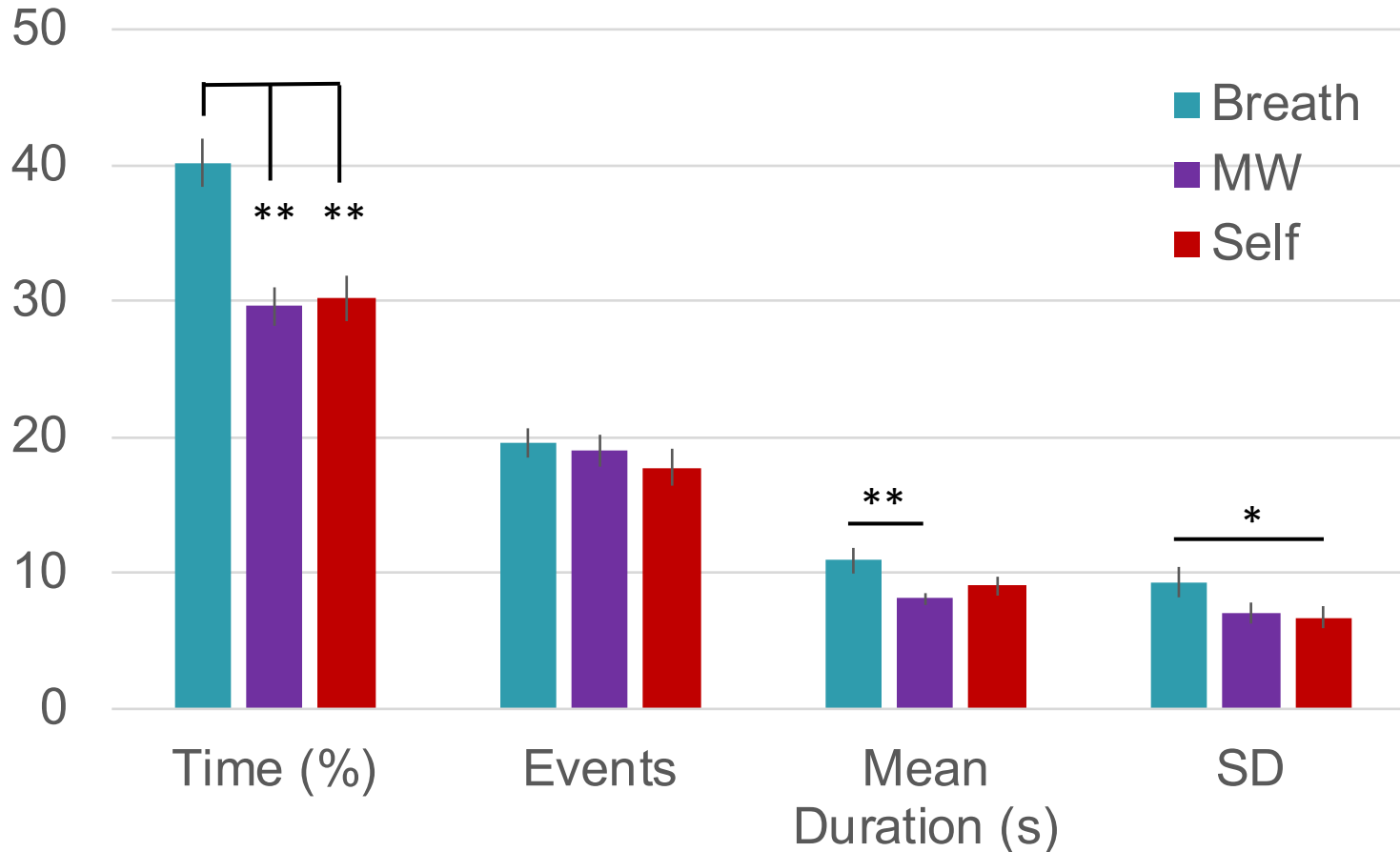
Overall, participants are engaging more with the breath

Weng *et al.,* (under review)

Measuring the Immeasurable:
Construct Validity - How do we know the attention metrics are meaningful?
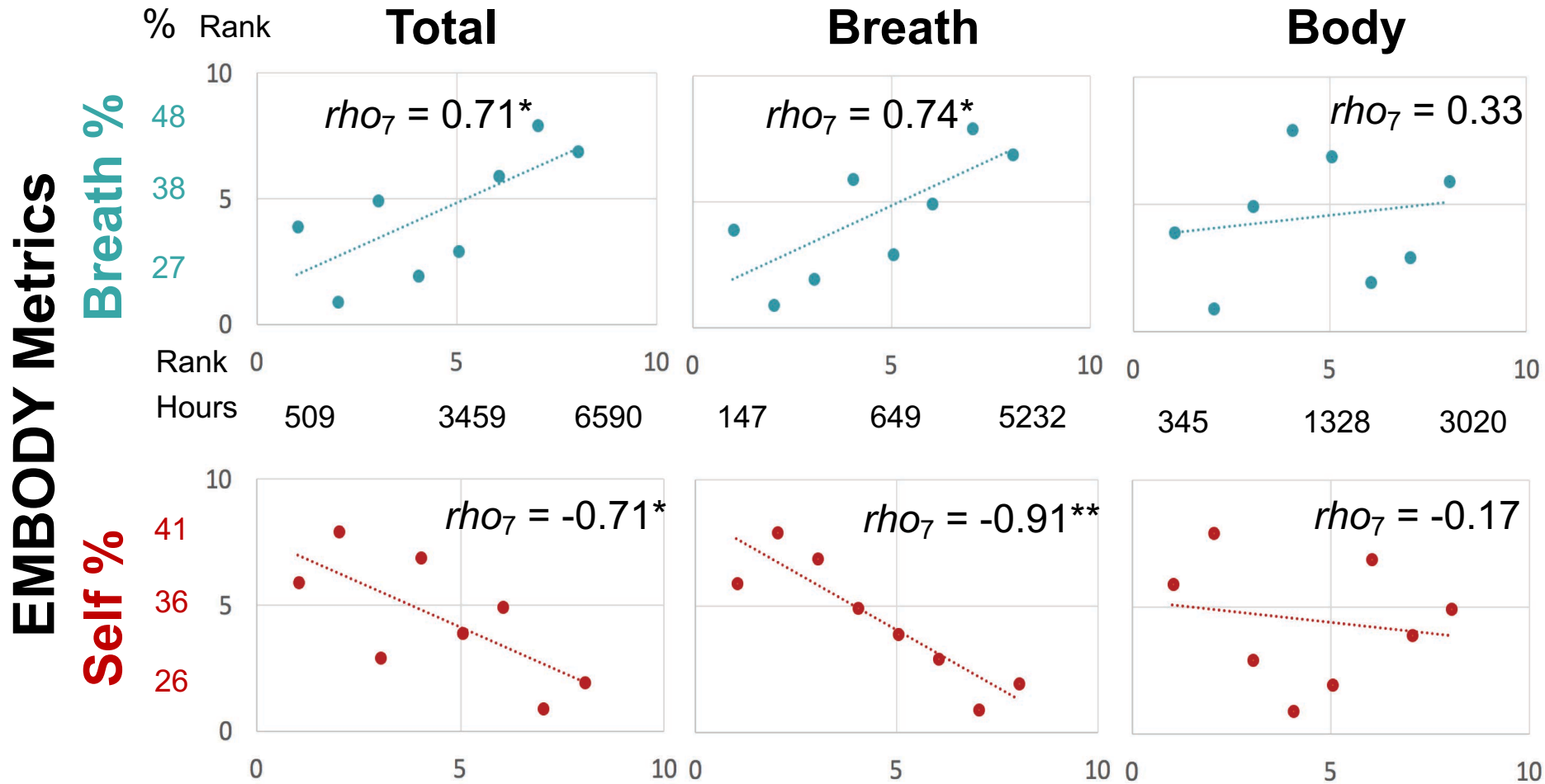
¯_(ツ)_/¯

Ratings of attention from meditation period (10 min) – no relationship!!

What about lifetime meditation practice?

EMBODY metrics and lifetime meditation practice

Lifetime Meditation Practice

Weng *et al.,* submitted

Preprint Available

EMBODY Study Conclusions

- Machine learning approaches applied to neural data can be used to identify and track distinct and fluctuating mental states during meditation (closer to reality)

- EMBODY Task metrics may provide a valid estimate of object of attention during meditation

  - Associations with lifetime meditation practice

- Individualized approach allows for more inclusivity and neural diversity

Centering diverse meditators
East Bay Meditation Center (Oakland, CA)

Increase diversity using community engagement
15 participants
80% racial and ethnic minorities, 53% LGBTQ+

Increased neural diversity with individualized brain approach:
Left-handers, neurological disorders, mental health conditions,
Psychotropic medications

eastbaymeditation.org

Weng, Ikeda, *et al.*, in prep

Current study: East Bay Meditation Center
Transformation of marginalized communities

Oakland, CA
embodystudy@ucsf.edu

Dialogue with His
Holiness the Dalai Lama
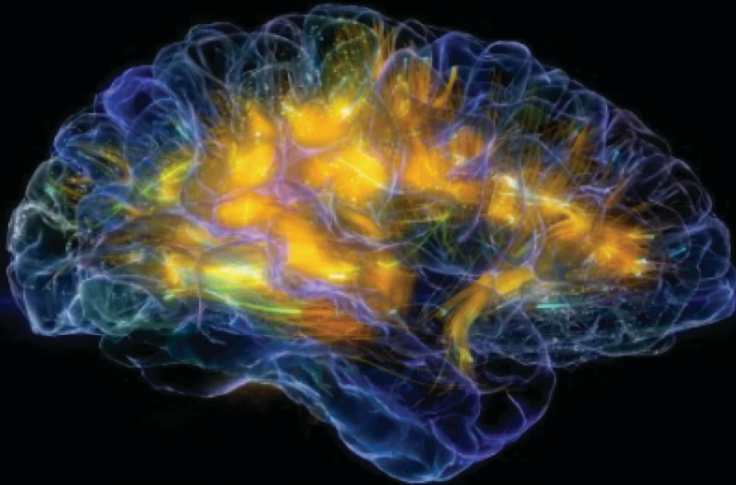*Ulaanbaatar, Mongolia 2016*

The EMBODY Study is the first to be able to read the mind during meditation

UCSF University of California, San Francisco
Osher Center for Integrative Medicine

NEUR SCAPE

With more research, we will have <u>unprecedented power</u> in understanding how meditation improves health and well-being.

- Uniquely tailor to people and populations

osher.ucsf.edu   neuroscape.ucsf.edu

Future Directions

- **Extend embody framework** to measure many practices
  - Different kinds of body awareness (body scan)
  - Other aspects of mindful attention (meta-awareness, nonjudgment)
  - Other meditation practices (open monitoring, compassion)
- **Map out mechanisms of action** for mindfulness-based interventions (less black box)
  - What attention metrics change through meditation and contribute to better health?
  - Precision medicine approaches to optimize treatments

Meditation for Regular People

- **Training qualities of attention**
  - Intentionally being present in the moment
  - Focus, narrow/expansive, calm, kindness, nonjudgment
- **Make it work for you** – every person is unique and different
- **Practice with what comes naturally**
  - What makes you *want* to pay attention
  - We all gravitate towards different kinds of internal and external stimuli
  - Bring into everyday life as well as formal practice
- **To expand and grow:**
  - Apply these skills to "growth areas"
  - With practice, can change "automatic pilot"

Thank you for listening!
Mentors and Collaborators:
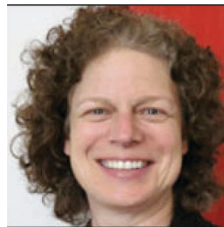
Integrative Medicine
UCSF Osher Center

UW-Madison
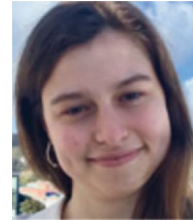
Rick Hecht, MD

Maria Chao, MPH, DrPh

Shelley Adler, PhD

Vierka Goldman

Sasha Skinner

Susanna McIntyre

Larrissa Duncan, PhD

East Bay Meditation Center
Oakland, CA

Mushim Ikeda

Xiaojing Wang

Duana Fullwiley

Cognitive & Affective Neuroscience
UCSF Neuroscape   UT-Austin   U Toronto   Center Healthy Minds, UW

Adam Gazzaley, MD, PhD

Melina Uncapher, PhD

David Ziegler, PhD

Jarrod Lewis-Peacock, PhD

Norman Farb, PhD

Richard Davidson, PhD

Regina Lapate, PhD