Neurobiology of Mindfulness and Brain Remodeling

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Mindfulness is Non-Judging Awareness of the Present Moment Experience

- The practice of non-judgmental awareness can interrupt the streams of random thinking and habitual behavior to reconnect with ourselves and with the true nature of this moment, leading to greater self-allowance and self-compassion and replacing automatic reactivity with wiser responsiveness.
Mindfulness Meditative States

- Focused Attention (FA)
- Open Monitoring (OM) (“Choiceless Awareness”)
- Effortless Awareness (“Meditative Bliss”)
- Loving Kindness (Compassion) Practice
Possible Specific Benefits of Mindfulness

- May cultivate healing through awareness
- May promote wholeness of our being—leading to contentment and peace of mind
- May promote tolerance and compassion (for self and others)
- May promote wisdom in thought and action (response v. mindless reactivity)
- May lessen destructive emotions (hatred, greed, etc.)
Potential Benefits

- General/normal population
- Professionals (burnout)
- Anxiety
- Depression
- Other psychiatric
- Chronic pain
- Fibromyalgia
- Cancer
- Addiction
- Sleep
Discussion Topics

- Behavioral Neuroanatomy (Identifying the usual suspects)
- Attentional Networks
- Interoceptive Awareness (Felt Body Sense)
- Stress Response
- Neuroplasticity (Brain Remodeling)
- Compassion and Forgiveness
- Epigenetics
- Putting It All Together??
Bodily States

- **Homeostasis**: all quiet, mind-body in harmony
  - Balance of sympathetic nervous system (SNS) and parasympathetic nervous system (PNS)

- **Allostasis** (stress response, SNS activation)

- **Allostatic load** (chronic stress response—maladaptive=persistent SNS overactivity)
Anatomy

- Frontal lobe
- Parietal lobe
- Temporal lobe
- Occipital lobe
- Pons
- Medulla oblongata
- Cerebellum
- Thalamus
- Cingulate gyrus
- Fornix
- Amygdala
- Hippocampus
- Parahippocampal gyrus
Fig. 1. Activation likelihood estimation maps (ALE) in the right temporoparietal junction projected on a partially inflated lateral view of the PALS-B12 brain atlas. The yellow to orange colors code the probability of activation, with brighter yellow indicating higher activation probability. Note that the activation peaks are localized very closely, whereas the extent of activation is slightly different across the four conditions.
Attentional Networks

- Default Mode Network
- Task Positive Attentional Networks
  - Salience Network
  - Executive Network
Default Mode Network (DMN)

- mPFC-PCC (+IP and LT regions)
- Mind wandering
- Very strong! (50% mental activity time here!)
  - (Must have positive evolutionary value)
- Self-referential, memory retrieval, adaptive planning, reflection, theory of mind, moral decision-making
- Distraction, impaired concentration, rumination, anxiety, unhappiness
Salience Network

- ACC (and vlPFC) + bilateral Insula
- Immediate present-moment processing
- Detection of relevant stimuli
- Central to meditation practice
Dorsal Attentional Network (DAN)

- dlPFC + pIParietal
- Executive Network
- Controls attentional resources to deal with immediate or future demands
- Relatively non-emotional ("inner critic").
Attentional Networks fMRI
Interoceptive Awareness

- Visceral, internal body milieu
  - (v. exteroceptive=outer senses, musculoskeletal, etc.)

- Obligate connection with feeling and emotion
  - (Mind-body connection)

- Signals to brain by the autonomic nervous system (ANS) and chemicals
Brainstem Nuclei

- NTS, PBN, PAG
- Not merely relay stations
- Bidirectional pathways with body and each other regulating metabolism
- Maps produced from body sensations include felt body states (primordial feelings)
- PAG instrumental in presenting primordial feeling to the insular cortex
- Close reciprocal connections between ACC and AI and with subcortical regions
Impaired Salience Connectivity

- Addiction and impulse control
- Alexithymia
- MDD associated with decreased PFC-limbic connectivity
Stress Response

- Subliminal triggers
  - SC>pulvinar>AM
  - ACC and AI

- Sensory/emotional trigger (amygdalae-hypothalamus) “fight or flight”

- Corticotropin releasing factor CRF—excitatory neurotransmitter within brain

- Pituitary-adrenal axis (cortisol)

- Sympathetic-adrenal (epinephrine, norepinephrine)

- Modulated by ACC-insula activation of VLM (inhibitory) and NA (parasympathetic, also inhibitory)

- Parasympathetic activity enhanced by meditation
Chronic Allostatic Load

- Persistently elevated stress (SNS response)
- Persistently elevated cortisol levels (including in brain > atrophy)
- Systemic—elevated blood pressure, glucose, heart rate, gut motility, etc.
- Often subliminal (below level of consciousness)?
Neuronal Plasticity

- The capacity to induce lasting changes in neurons, neural pathways and glial (supporting) cells
- Measured by static and functional MRI (cell layers, pathways and regional metabolic activation), EEG, magnetoencephalography
- Mindfulness meditation
  - Promotes neuroplasticity
  - Offers neuroprotection?
  -Enhances equanimity, mood, emotional stability, decision-making
Fortifying the Salience Network

- The most striking phenomenon with meditation
- High activation, cortical thickening and strengthening of connection ACC-AI
- Attentional Resources (ACC) directed to interoceptive awareness (AI)
Implications (ACC-AI)

- Awareness promotes healing—to make whole, not “cure”
- Redirection from DMN (less dyphoria and rumination)
- Moving from “fix it” mode to “being” mode
- Pathway activation promotes “relief”
- Pathway resonance affects subcortical regions—AM (stress reduction), LC (Optimizing brain function, neuroprotection?), PAG (modulates pain matrix)
Triangle of Awareness

Sensation (felt body sense)

Feelings/emotion  Thoughts
Focusing (Gendlin, Cornell)

- Guiding interoceptive awareness (with partner—provides reflection)
- Locating and labeling the felt body sense
- Associating with thoughts and feelings
- Positive association > resonance > shift in body sensation (relief)
Attentional Networks fMRI
Meditation Weakens DMN

- Decreased connectivity vPMC-PCC
- Deactivation of PCC
- Decreased self-referential cognitive processing
- Decreased rumination, increased equanimity
- Decreased suffering; improved sense of wellbeing
PCC Activation
Distracted Awareness

Distraction
\(n = 64\)

Interpreting
\(n = 56\)

“I’m associating …the red with sort of the… the intrusion of thought”

“…I was like, ‘Whoa that is a lot of red’ and then I noticed my mind was going ‘Whoa that is a lot of red’ and I got a little bit caught up in how I was going to explain that to you”

Efforting
\(n = 19\)

Discontentment
\(n = 14\)

“I worried that I wasn’t using the graph as an object of meditation, so I tried, like, to look at it harder or somehow pay attention more to it”

“I brought up memories of uh, embarrassment, regret, um, interpersonal unskillfulness”
PCC Deactivation

**Undistracted Awareness**

**Concentration**

\( n = 99 \)

“Very smooth. It was very easy to concentrate, or a concentrated meditation this time…the blue part”

**Observing sensory experience**

\( n = 76 \)

“I started observing how my mind was doing, and then it immediately went back into blue…”

**Observing sensory experience**

**Effortless Doing**

Not ‘efforting’

\( n = 48 \)

“Toward the middle I had some thoughts which I don’t see on the graph maybe because I let them kind of flow by”

“I noticed …that the more I relaxed and stopped trying to do anything, the bluer it went”

**Contentment**

\( n = 28 \)

“I was setting the intention to cultivate equanimity…when I set that intention, the blue spiked downward”
Other Effects of Meditation

- R>L prefrontal activity shift, decreased amygdala activation (happier)
- Increased hippocampal volume/density (memory)
- Increased precuneus-IPL connectivity (3rd person perspective)
- Lateral shift of DMN
- Decreased D to V PMC connectivity (less emotional reaction to judgment)
- Increased VL-VM PFC/AM connectivity (reassurance, inhibitory to judgment-stress response)
- Affect labeling-activates the rvlPFC and deactivates AM
Loving Kindness Practice

- Early stages of investigation
- Increased activity in AM, R mid-temporal region, TPJ
- Unique among meditation practices for cortical thickening of the angular gyrus?
- “Hypoequanimitity” preferable to “Hyperempathy”
  - Emotional regulation distinguishes empathy from emotional contagion and distress
- Self-compassion v. self-esteem
Forgiveness (Compassion)

- Recruits dlPFC, precuneus-IPL
  - dlPFC-apply cognitive reappraisal to regulate emotional response
  - Precuneus-3rd person perspective
- Forgiveness activates salience network and IPL
- Resentment=tension
- Forgiveness=relief (strong precuneus-IFP connection)
Locus Coeruleus (Craigmyle, 2013)

- Virtually the sole source of central norepinephrine (cNE) to the cerebral cortex and hippocampus and principal source to the thalamus
- Activated by ACC, enhanced by PNS (e.g. meditation, VNS?)
- LC activation-increased wakefulness, cortical arousal, receptivity of present-moment sensory experience, anti-nociception
- cNE-rapid modulation of cortical circuits and energy metabolism, slower for neuroplasticity (via glial cells?) and inflammatory responses (e.g. suppression of cytokines and enhancement of BDNF)
- Integrated cNE-pNE systems form principal neuromodulatory system for homeostasis (including neurons and glial cells)
- c-NE (also serotonin) mediation of thalamic reticular nuclei (RN)-EEG waves: 40Hz gamma synchrony (enhanced in meditation)
- Enhancement of working memory, of hippocampal memory consolidation via blAM, and attention shifting
Epigenetic Inheritance

Epigenetic Inheritance: Alterations in gene expression that are passed onto the next generation, but where the DNA itself remains unchanged.

NOVA clip on epigenetics if you want more background: http://www.pbs.org/wgbh/nova/body/epigenetics.html
Inherit Parents FEAR
Environmental influence

Direct stress exposure

Multigenerational stress influence

Epigenetic modifications
- in somatic cells
- in germ cells

Disease progression?

Epigenetic disease programming?

Epigenetic inheritance:
- DNA methylation
- Histone modification
- PIWI-associated interfering RNAs (piRNAs) and microRNAs

Transgenerational stress influence
“Monopoly of Rumination”

- Out of balance to mind at the expense of body
- Meditation practice as a rebalancing or redistribution (Beth Roth)
- Key: Recruitment of the task-specific salience network facilitating the mind-body connection and promoting healing
- Passing “peace of mind” on to future generations
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