Meditation as a Modulator of Stress Effects on the Mind and Body

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Overview

I) Brief Review of Normal Structure and Function of Central Nervous System

II) Physiological Effects of Stress on the Mind and Body

III) Physiological Effects of Meditation on the Mind and Body
Brief Review of Normal Structure and Function of Central Nervous System
CNS Structure and Function

Structure – refers to “nuts and bolts” of the brain

Function – refers to inter/intra neuronal functioning

If we compare the brain to a computer, structure would refer to the hardware (computer, monitor, mouse, etc.) while function would refer to the software code while causes the computer to run smoothly.
Really More of a Continuum
(Sadock 2007, pg 70)

Neuron → Neuronal Network → Broadman Groups or Areas → Larger Structures → Whole Brain

*It is important to understand this continuum because changes at the neuronal level over time can actually effect change at a larger level (even whole brain volume)
Brain Structure
(Sadock 2007, pg. 86)

Broken Into 3 Major Groups:

1) Forebrain
2) Midbrain
3) Brainstem: Cranial nerves, vital centers (arousal, heart rate, origin of neurotransmitters), cranial nerves
Forebrain
(Sadock, 2007, pg 87, table 3.1-3)

Telencephalon
   Cerebral Cortex
   Hippocampus
   Amygdala
   Striatum/Basal Ganglia

Diencephalon
   Thalamus
   Hypothalamus
   Epithalamus
Cerebral Cortex
Cortex (lobes)
(Sadock 2007, pg 85, table 3.1-1)

**Frontal**: language (left), movement (right), executive function, motivation, voluntary movement

**Temporal**: Audition, language (left), some memory and emotion given proximity to limbic system

**Parietal**: Tactile sensation, visuospatial (right), reading/calculation (left), sensory integration

**Occipital**: Vision
Cortex is also divided into 47 different broadman areas based on differences in cellular arrangements.

Prefrontal Cortex: anterior most portion of frontal lobe (many small divisions). Executive functioning, motivation, attention, sequencing of actions, planning. Can be involved in emotion regulation, cognitive re-evaluation, reconsolidation, and mental flexibility.
Prefrontal Cortex

[Image: Prefrontal1.png]

Specialized Areas of Cortex

**Insular Cortex/Insula**: Refers to deep cortex of the temporoparietal junction. Serves a role in body awareness, perception of visceral sensation, awareness of heart rate and respiratory rate, and response to pain (Ngo 2013)
Forebrain
(Sadock 2007 pg. 89)

“Top” – Cerebral Cortex

“Bottom” –
  Basal Ganglia (modulation of movement)
  Limbic System/Cingulate Cortex
Limbic System/Cingulate Cortex (Ngo 2013)

Limbic system

Amygdala: Emotion Processing
Hippocampus: Memory Processing

Cingulate Cortex: Known as “limbic cortex”

Anterior Cingulate: Attention
Posterior Cingulate: Understanding Context
Limbic System/Cingulate Cortex

- **Cingulate gyrus**: This area, together with the parahippocampal gyrus and the olfactory bulbs, comprises the limbic cortex, which modifies behavior and emotions.

- **Fornix**: The fornix is a pathway of nerve fibers that transmits information from the hippocampus and other limbic areas to the mamillary body.

- **Septum pellucidum**: A thin sheet of nervous tissue connects the fornix to the corpus callosum.

- **Column of fornix**: This tiny nucleus acts as a relay station, transmitting information to and from the fornix and thalami.

- **Mamillary body**: This structure influences physical activity via the basal ganglia, the large clusters of nerve cell bodies below the cortex. Limbic midbrain areas also connect to the cortex and the thalamus.

- **Olfactory bulbs**: The connection of these structures with the limbic system helps explain why the sense of smell evokes long-forgotten memories and emotions.

- **Amygdala**: This structure influences behavior and activities so that they are appropriate for meeting the body’s internal needs. These include feeding, sexual interest, and emotional reactions such as anger.

- **Parahippocampal gyrus**: With other structures, this area helps modify the expression of emotions such as rage and fright.

- **Hippocampus**: This curved band of gray matter is involved with learning and memory, the recognition of novelty, and the recollection of spatial relationships.

Limbic System/Cingulate Cortex

Figure AB-16: Limbic System

Diagram colors are consistent with Figure AB-17.

Forebrain
(Sadock, 2007, pg 87, table 3.1-3)

Telencephalon

  Cerebral Cortex
  Hippocampus
  Amygdala
  Striatum/Basal Ganglia

Diencephalon

  Thalamus: relays sensory and motor signals/information to cortex (Sherman 2000)
  Hypothalamus
  Epithalamus
Hypothalamus 
(Sadock 2007, pg 121)

Releases a multitude of hormones, including:

- Corticotropin Releasing Hormone (CRH)
- Adrenocorticotropic Hormone (ACTH)
- Thyrotropin-Releasing Hormone (TRH) ➔ Thyroid Stimulating Hormone (TSH)
- Gonadotropin-Releasing Hormone (GnRH) ➔ Luteinizing hormone (LH) and Follicle-Stimulating Hormone (FSH)
- Growth Hormone Releasing Hormone (GHRH) ➔ Growth Hormone (GH)
Typical Hypothalamic Feedback Loop
Major Neurotransmitters (NTs) (Sadock 2007, pgs 100-109)

Dopamine: cardiac, movement, breast feeding (Schizophrenia)

Norepinephrine/Epinephrine: sympathetic, focus (anxiety, depression)

Serotonin: gut (anxiety, depression)

Histamine: allergy/inflammation, sedation, weight gain

Acetylcholine: movement, parasympathetic (anticholinergic toxicity)

Gamma-Aminobutyric Acid (GABA): major inhibitory NT

Glutamate: major excitatory NT
Physiological Effects of Stress on the Body
Stress

What does stress even mean?

Broadly defined as:
Physical/Pain
Grief or Loss
Mental Illness (Depression, Schizophrenia)
Early Childhood Adversity/Trauma

Largely defined as when demands in life outweigh our ability to cope with them
Stress and Pain

Pain is an incredibly complex phenomenon.

The way we perceive pain is multifactorial, from the objective cellular level (automatic reflexes) all the way to the very subjective emotional level.

Even our cellular understanding of pain isn’t complete. Why would a serotonergic medication help treat pain if in theory the only receptors for pain are opioid?
Goal with Stress and Pain

Much like with pain, our goal with stress is to help explain its relationship to the body and to then work towards learning to accept it and adjust ourselves to function with both stress and pain.

A completely stress-free world is a fantasy. However, how we choose to respond to the stress in this world may make all the difference.
PsychoNeuroEndocrinology
(Sadock 2007 pgs 122-125)

Hypothalamic-Pituitary-Adrenal Axis:
High levels of stress cause increased CRH, ACTH, and cortisol levels. Over time this leads to reduced hippocampal size and enlarged adrenal glands. Chronic hypercortisolemia results in reduced immune function.

Can lead to chronic fatigue, social withdrawal, impaired sleep, and decreased concentration. Can also lead to mood disturbance. Seen in anxiety and PTSD.
PsychoNeuroEndocrinology
(Toufexis et al, 2014)

Hypothalamic-Pituitary-Gonadal Axis:
High cortisol levels, especially over time, also appear to inhibit testosterone and estrogen secretion

Testosterone: mood, energy, strength, sperm production
Estrogen: mood, libido, sense of well-being, fertility

Both of these hormones can impact the size of the hypothalamic nuclei and corpus callosum, the neuronal density in the temporal cortex, the organization of language ability, and the responsivity in Broca’s motor speech area
Hypothalamic-Pituitary-Thyroid Axis:
Stress has also been shown to decrease conversion of T4 to T3, which means you have less active thyroid hormone circulating in your body

Signs of hypothyroidism include: fatigue, decreased libido, memory impairment, irritability, and depression
Severe psychosocial stress can cause growth hormone deficiency and delay puberty, and this can be severe enough to result in significant short adult stature.

Children with Growth Hormone Deficiency see improved cognitive functioning when growth hormone is supplemented.
INFLAMMATION

http://livingwellnessblog.wordpress.com/2012/12/11/inflammation-where-there-is-smoke-there-is-fire/
PsychoNeuroImmunology  
(Sadock 2007, pgs 125-126)

Numerous effects of stress on immunology (cortisol known to cause immunosuppression)

One study assessed medical students prior to examination and during final examination. Examination stress resulted in less natural killer T cell activity, decreased numbers of T cells, and decreased interferon production.
Caregivers of people with chronic illnesses have been found to have impaired antibody responses, more days of illness, and longer latency for wound healing.

HIV patients who rate severe stress experience lower CD*+ T Cell numbers and lower natural killer cell counts.
PsychoNeuroImmunology (Sadock 2007, pgs 125-126)

Mental Illness:

**Schizophrenia**: increased interferon (helps generate immune response), lower interleukin-2 (pro-inflammatory).

**Depression**: increased proinflammatory interleukin-1 and interleukin-6, increased CRP.

**Chronic Fatigue Syndrome**: alternating overactive immune activation and suppression
PsychoNeuroImmunology
(Sadock 2007, pgs 125-126)

TAKE HOME: Stress simultaneously

1) Creates chronic, low level inflammation in the body which promotes systemic inflammation (linked to cancer, heart disease, autoimmune conditions, and depression)

AND

2) Suppresses acute inflammation needed to fight off infections
Physiological Effects of Stress on the Brain
Effects of Hypercortisolemia
(Issa 2010, Gray 2013)

• Chronic elevated levels of cortisol in the cerebral vasculature and CSF

• Reduced level of Brain-Derived Neurotrophic Factor (BDNF)

• Decreased volume of hippocampus
FIGURE 1. Atrophy of the hippocampus in depression.

## Chronic Stress Effects on CNS Structures

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<thead>
<tr>
<th>Structure</th>
<th>Effect of Stress</th>
<th>Source</th>
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“Activation” refers to increased blood flow and/or increased metabolism.
How Do CNS Structures Actually Change Volume in Response to Stress?

Chronic high levels of stress can actually change the expression of hundreds of genes! (Karssen 2007)
Physiological Effects of Meditation on the Mind and Body
Cognitive Behavioral Therapy
Sadock, 2007, pgs. 953-961

Thoughts
Feelings
Behaviors
### Chronic Stress Effects on CNS Structures

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Prefrontal Cortex “Top-Down” Control Over Amygdala (Kumar 2014)

http://www.nature.com/nm/journal/v18/n2/fig_tab/nm.2671_F1.htm
Benefits of Meditation for the Brain

Simultaneously providing both “top-down” and “bottom-up” rewiring of the brain (comprehensive total brain exercise)

“Top-Down” by concentrating and focusing very hard while attempting to minimize impulses from lower brain

“Bottom-Up” by increasing our awareness of our body and in particular our heart rate and respiratory rate, which in turn allows the cortex to calm, decrease extraneous noise, and focus/concentrate
Maybe Also “Side to Side?”
(Kurth 2014)

Meditation thickens the corpus callosum, increasing “cross talk” between left and right cerebral hemispheres.

Meditation can impact frontal asymmetry. Keune reported that mindfulness meditation helped change the asymmetry pattern from withdraw to approach/motivation.

Moynihan reported that meditation helped to maintain left frontal asymmetry (where slipping to the right was undesirable)
MAKING WAVES
The brain wave spectrum divides into 5 bands with different associated states:

- DELTA WAVES (δ), 0.5–4Hz:
  Deep unconscious, intuition and insight

- THETA WAVES (θ), 4–8Hz:
  Subconscious creativity, deep relaxation

- ALPHA (α) waves, 8–13Hz:
  “Spacy” and dreamy state, receptive and passive

- BETA (β) waves, 13–30Hz:
  Conscious thought, external focus

- GAMMA (γ) waves, 30–100Hz:
  Not well understood, but linked to perception and alertness or anxiety

During successful meditation, the subject typically starts off with high beta (thinking), then experiences more alpha, followed by more theta and finally delta, the deepest level. After some time, the reverse process takes place, bringing the person back to beta feeling awake and refreshed, sometimes with new insights.
Can Meditation Reverse the Effects of Stress on the Brain?
Meditation Reverses Effects of Chronic Stress

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What About Meditation and Immune Function?
Meditation Improves Immune Function

Witek-Janusek 2008:

Women newly diagnosed with early stage breast cancer who were given mindfulness meditation had higher levels of healthy immune markers (interferon, interleukins) than controls. They also experienced improved coping skills and quality of life.
Meditation Improves Immune Function

Rosenkranz 2013:

Subjects were given a small “burn” with capsaicin cream. Those who partook in mindfulness had a much smaller post-test inflammatory response.
How About the Endocrine System?
Meditation and Cortisol

Turakitwanakan 2013: Medical students given a four day mindfulness meditation course had significantly lower serum (blood) cortisol levels.

Kang 2012: Breast cancer patients received three hours of mindfulness meditation instruction per week for eight weeks, resulting in lower salivary cortisol, not to mention decreased perceived stress, improved coping, and decreased psychological stress.
Other Organs/Diseases?
Park 2014:
Mindfulness meditation resulted in reduction in systolic and diastolic blood pressure, mean arterial pressure, heart rate, and muscle sympathetic nerve activity, all critical to health in chronic kidney disease (population of study)

Manchanda 2014:
Meditation can improve outcomes in individuals with coronary artery disease by reducing adverse cardiovascular events (heart attacks) by 48% over a 5 year period.
The benefits to meditation for the mind and the body are plentiful. That being said, is it possible that there can be too much of a good thing?
QUESTIONS/THOUGHTS???
References (in order of appearance)


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