Mindfulness Training in Marines

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Outline

- Background
- Methods
- Results
- Conclusions
Resilience

- The ability to positively adapt to severe stress, trauma, and adversity.

- Complex construct:
  - temperament and personality (e.g., ego resiliency),
  - cognitive functions (e.g., problem-solving),
  - access to environmental resources (e.g., supportive relationships)

- Important to cope with traumatic events and prevent the development of psychopathology
Why do we care?

- Need for developing of better strategies – based on objective and quantifiable measures - for building resilience

- Identification of brain regions and mental activities to be targeted for modification through training
Interoception

- Sensing and representation of sensations from inside the body
  - Breathing, hunger, thirst, itch
- Body-relevant information is processed by the INSULA

- Thinking, feeling and anticipating what is going to happen is integrated in the **anterior insula**
Interoception

- Anterior Cingulate Cortex
  - Gets from the insula “what is going on”
  - Prepares the body to take action to maintain bodily homeostasis, if needed
Interoception Example

Typical Caffeine Response:
- Thalamus → Insula
- Jittery
- Alert/Wired
- Stomach Sensations

One Hour Later

Predicted State

vs

Actual State

Barista Must’ve Given Me Decaf!
Must go back to Starbucks!
Interoception: Inspiratory Breathing Load (IBL)

fMRI (functional magnetic resonance imaging) BOLD (blood-oxygen level dependent) brain response to IBL
Interoception

- Several studies linking body relevant processing (interoception) and resilience (adventure racers, Diana Nyad, RedBull Athletes, Navy SEALs, Olympians)
Interoception

- In response to inspiratory breathing load, elite performers demonstrate:
  - Anticipation: amplification
  - Reaction: attenuated
  - Recovery: attenuated

Paulus et al., PLoS One, 2012
Mindfulness

— The awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment — Jon Kabat-Zinn

- Mindfulness involves:
  - Regulated attention
  - Knowledge that events are momentary
  - Lack of emotional or cognitive appraisal to events
Mindfulness

- Mindfulness training (MT) reduces stress associated in people with
  - Chronic medical conditions
  - Mental health conditions

Hofmann et al., 2010, Kabat-Zinn et al., 1985; Carlson et al., 2007, etc.
Mindfulness

- MT results in anatomical and functional changes in regions involved in interoception

 Increased cortical thickness; Lazar et al., 2005; Neuroreport

 Increased activation; Zeidan et al., 2011; J Neurosci
Military personnel: increased risk for cognitive, emotional, and physiological compromise associated with prolonged exposure to stressful environments (Kok et al., 2012; Liberman et al., 2005; Vasterling et al., 2006)

MT may have some beneficial effects in military populations
Aim

- Does MT modulate the brain’s response to an aversive stressor in active duty infantry Marines?
Exploratory Aims

- Does MT modulate other non-neural markers of stress?
  - Physiology: Heart rate and breathing rate
  - Biomarkers of stress: norepinephrine, neuropeptide Y
  - Behavioral measures: sleep quality, resilience characteristics, mindfulness
Methods
Participants

- Convenience sample of two Marine infantry battalions scheduled to undergo pre-deployment training

  **Mindfulness Training**

  - 4 platoons assigned to the MT group (n = 153)
  - 4 platoons assigned to the control group (n = 134)

  **fMRI**

  - 21 Marines from the MT group
  - 21 Marines from the control group
Study Design

8 weeks

Assessment & fMRI

T1

Mindfulness Training

OR

Control

Assessment

T2

Infantry Immersive Trainer

Assessment

T3

14 days

fMRI

T3

5-10 days

11-12 Weeks
Mindfulness-Based Mind Fitness Training (MMFT)

- Created and delivered by a former U.S. Army officer with many years of mindfulness practice and training in MBSR and trauma resilience
- Contains many features of the well-established Mindfulness-Based Stress Reduction (MBSR) protocol developed by Kabat-Zinn (Kabat-Zinn, 1982)
- 20-hour course taught over 8 weeks
  - Eight 2-hour sessions of classroom instruction
  - 4-hour workshop with a longer session of silent practice to refine skills
  - Daily homework
- Primary training components geared towards military environment:
  - Mindfulness, stress resilience, concrete application for operational environment
  - Didactics: Mindfulness, military stress inoculation training, complex decision making
  - Provides skills and information for understanding and regulating the effects of stress on the mind and body
Infantry Immersive Trainer

- Evaluation of recovery from stress
- One-day training in a mock village; 3 different scenarios with increasing complexity
  - Passive village patrol
  - Meeting village leaderships
  - Complex ambush
- Close-quarters combat scenarios, simunitions (i.e., training ammunitions) and realistic sensory (e.g., smells, sounds) and environmental stimuli (e.g., interpreters, pyrotechnics)
# Primary Measures

<table>
<thead>
<tr>
<th>Domain</th>
<th>Method</th>
<th>Outcome Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interoception</td>
<td>Insula probe via fMRI task</td>
<td>% signal change</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BOLD response</td>
</tr>
<tr>
<td>SAM HPA</td>
<td>Blood plasma ELISA</td>
<td>NPY</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NE</td>
</tr>
<tr>
<td>Physiology</td>
<td>Real-time telemetry</td>
<td>Heart-Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Breathing rate</td>
</tr>
<tr>
<td>Behavior</td>
<td>Sleep quality</td>
<td>Pittsburgh Sleep Quality Index (PSQI)</td>
</tr>
<tr>
<td></td>
<td>Resilience characteristics</td>
<td>Response to Stressful Experiences Scale (RSES)</td>
</tr>
<tr>
<td></td>
<td>Mindfulness</td>
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</tbody>
</table>
Interception: fMRI

- Functional Magnetic Resonance Imaging (fMRI) measures blood-oxygen level dependent (BOLD response), which is an indirect measure of neural activity.

- Non-hypercapnic inspiratory breathing load: 40cmH₂O/L/sec (subjective sx, not CO₂ or O₂ levels)

- Continuous Performance Task: press a button corresponding to the direction pointed by an arrow on a screen

- Background color of the arrow will serve as a cue to the impending presentation of the breathing load
Interoception: fMRI

- fMRI Component: Response accuracy and reaction time
- Behavioral component: breathing restriction prior to entering scanner
- 10 cm visual analog scale (VAS)
  - “Not at all” to “Extremely”
  - 16 dimensions:
    - Pleasant; unpleasant; intense; tingling; fear of losing control; faintness; fear of dying; unreality; hot/cold flashes; trembling; choking; abdominal distress; chest pain; palpitations; sweating; dizziness.
Interoception: fMRI

- Anatomically constrained a priori regions of interest:
  - insula; anterior cingulate cortex

- Group Level Analysis:
  - R Linear Mixed Effects
    - Fixed: group (MMFT or Control), task condition (breathing: anticipation, load, post-load, post-anticipation), time (T1 and T3)
    - Random: subject
Biomarkers

- Plasma concentrations of **neuropeptide Y and norepinephrine**.
- Neuropeptide Y is co-released with norepinephrine
  - indicator of sympathetic activation.
- released during intense or prolonged sympathetic activation
- well-known stress modulator
Primary physiological measures were **heart rate** and **breathing rate**.

These were measured at the IIT facility and included continuous monitoring through the following sequence of periods:

- rest (45 minutes)
- anticipatory (10 minutes)
- stress (30 minutes)
- recovery (10 minutes)
- rest (45 minutes)
Behavioral

- **Five Facets of Mindfulness Questionnaire** (FFMQ; Baer et al., 2006): observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience.

- **Response to Stressful Experiences Scale** (RSES; Johnson et al., 2011): 6-processes that promote resilient responses to high-magnitude stressors (active-coping, spirituality, cognitive flexibility, meaning-making, self-efficacy, restoration).

- **Pittsburgh Sleep Quality Scale** (PSQL; Buysse et al., 1989): subjective sleep quality and disturbance over the preceding 1-month time interval.
Results
Demographics/Behavioral

There were no significant main effects or interaction effects.

**Table 1. Demographics and Self-Report Measures of Study Participants**

<table>
<thead>
<tr>
<th>Variable</th>
<th>MMFT (n=19)</th>
<th>Control (n=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean(Std)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>22.35(3.30)</td>
<td>20.81(1.10)</td>
</tr>
<tr>
<td>Years of Education</td>
<td>12.37(0.76)</td>
<td>12.00(0.00)</td>
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</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>MMFT T1</th>
<th>Control T1</th>
<th>MMFT T2</th>
<th>Control T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean/Std</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pittsburgh Sleep Quality Index</td>
<td>9.93(4.62)</td>
<td>6.57(3.76)</td>
<td>8.79(4.48)</td>
<td>6.79(3.80)</td>
</tr>
<tr>
<td>Response to Stressful Experiences Scale</td>
<td>58.92(13.11)</td>
<td>66.10(13.44)</td>
<td>59.42(11.25)</td>
<td>64.20(14.13)</td>
</tr>
<tr>
<td>Five Facets of Mindfulness Questionnaire</td>
<td>129.55(14.50)</td>
<td>125.55(17.24)</td>
<td>120.64(7.75)</td>
<td>128.44(15.57)</td>
</tr>
</tbody>
</table>

*MMFT = Mindfulness-Based Mental Fitness Training; T1 = baseline assessment; T2 = post-training assessment.*
Interoception Ratings

- **VAS Ratings**: For both groups: pleasantness decreased with increasing load; unpleasantness and intensity increased for 20 and 40 cm H2O.
Interoception: fMRI

- **Latency**: Individuals longer latencies for anticipation and the post-breathing load

- **Accuracy**: There were no main effects or interaction effects for accuracy.

![Latency: Time by Condition](image)
Table 2. Group-by-time interaction of breathing restriction on brain activation

<table>
<thead>
<tr>
<th>Volume</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>Brain Area</th>
<th>BA</th>
</tr>
</thead>
<tbody>
<tr>
<td>256</td>
<td>44</td>
<td>3</td>
<td>-4</td>
<td>Right Insula</td>
<td>13</td>
</tr>
<tr>
<td>256</td>
<td>-41</td>
<td>-8</td>
<td>2</td>
<td>Left Insula</td>
<td>13</td>
</tr>
<tr>
<td>256</td>
<td>1</td>
<td>42</td>
<td>-2</td>
<td>Right Anterior Cingulate</td>
<td>32</td>
</tr>
<tr>
<td>320</td>
<td>-9</td>
<td>53</td>
<td>-14</td>
<td>Left Medial Frontal Gyrus</td>
<td>11</td>
</tr>
</tbody>
</table>

*BA = Brodmann Area; Volume (uL), center of mass coordinate, and brain area based on the voxel-wise mixed model group-by-time interaction of breathing restriction.*
Interoception: fMRI

Results: Group-by-Time

Right Anterior Insula

% Signal Change

Control  MMFT

T1  T3

No Plug  Plug

Baseline  Anticipation  Breathing Load

Breathing tube

Plug  25% chance of plug

40 cmH2O/sec

6-12 sec

40 sec
Interoception: fMRI

Results: Group-by-Time

Anterior Cingulate Cortex

% Signal Change

Control  MMFT

T1  T3
Following MT, infantry Marines demonstrated a pattern of neural activation that is more similar to elite performers and experienced meditators during an aversive challenge.
Physiology

- Heart rate during the 10-minute anticipatory period prior to IIT was higher for the MT group.
- The MT group showed quicker heart rate recovery during the 10-minute period immediately following IIT.

Johnson et al., AJP (2014)
No differences between groups in breathing rate during the anticipatory or stress periods.

10-minute recovery period, the mean breathing rate for the control group did not significantly differ from peak response.

The mean breathing rate for the MT group:
- Decreased faster from peak during the stress period
- was significantly lower than the rate for the control group during both the 10-minute recovery and the 45-minute rest period.
Physiology

- For neuropeptide Y:
  - Control group showing significantly higher levels of neuropeptide Y 45 minutes after stressful training,
  - MT group had recovered to near baseline levels.

![Graph showing plasma neuropeptide Y concentrations in Marines receiving mindfulness training (MT) or training as usual (Control).]
No significant effects of MT on norepinephrine concentrations.
Conclusions
Conclusions

- **Behavioral**: MMFT training did not modulate self-report assessment, VAS ratings during the breathing restriction task, or task performance.

- **Heart and breathing rate**: greater response to stress followed by a quicker recovery with MT

- **Neuropeptide Y**: MT group demonstrated faster recovery of sympathetic function.

- **fMRI**: MT resulted in decreased in insula and ACC activation in response to an aversive interoceptive stimulus, which may represent more efficient neural processing of internal stressors.
Conclusions

- MT alters function in higher-order brain regions that in turn modulates autonomic outflow to heart rate and breathing rate control centers and sympathetic activation.

- MT demonstrated beneficial effects across multiple domains indicating enhanced recovery from stress.

- Effects found in non-clinical sample suggesting responses to stress may be improved prior to stress exposure.

- MT may serve as a training technique to modulate the brain’s response to stressors, which may help individuals develop better coping abilities.
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