Heart Rate Variability Biofeedback

“Increasing RSA”
Ordinary Breathing produces three HR frequencies, HF, LF, & VLF.

Progression to approx. 6 BPM, (Diaphragmatically) in experienced breathers produces a single summated peak at about 0.1 hz:

**Vaschillo’s Resonant Frequency Theory**

Daily practice in this state increases homeostatic reflexes.
RFT: Notice trend from three waves to a dominant 1 Hz Wave
Average RR-interval spectral power and RR intervals from 10 healthy supine subjects breathing to a nominal tidal volume of 1000 mL at seven breathing rates. From Eckberg DL, Circulation 1997;96:3224 –3232 (originally Brown et al.,1993)
Resonance

Dictionary Definition:

- The increase of amplitude of oscillations of an electric or mechanical system due to a periodic force whose frequency is equal or very close to the natural undamped frequency of the system.

Transfer functions, phase angles, and such

Resonance Frequency Biofeedback Training
EFFECTS OF HRV BIOFEEDBACK ON HEART RATE

Graph showing the effects of HRV biofeedback on heart rate over time.
Biofeedback-induced RRI and SBP

Spectrums of Biofeedback-induced RRI and SBP
Resonance in Physiological Systems

Resonance is a property of an oscillating system in which perturbations at specific frequencies produce large increases in oscillation amplitudes.

A system has resonance properties if two processes (functions) of the system interplay against each other in a feedback relationship.
Reaction of Aperiodic and Resonance Systems to Perturbation Stimuli

Resonance frequency:

\[ F[\text{Hz}] = \frac{I}{T[\text{s}]} \]
The pendulum may oscillate because kinetic and potential energies of mass are linked with each other by feedback. The process of kinetic energy change elicits a process of potential energy change and vice versa.
To understand why human beings are more sensitive to some frequencies than to others, it is useful to consider the human body as having sub-systems, where each sub-system has its own resonant frequency.
EACH BODY SUB-SYSTEM HAS A RESONANCE FREQUENCY BAND

Mechanical Resonance

Eyeball, Intraocular structures (20-90 Hz)
Head (axial mode) (20-30 Hz)
Shoulder girdle (4-5 Hz)
Chest wall (5-10 Hz)
Lower arm (16-30 Hz)
Arm (5-10 Hz)
Spinal column (axial mode) (10-12 Hz)
Hand (30-50 Hz)
Abdominal mass (4-8 Hz)
Seated person
Standing person
Legs (Variable from ca. 2 Hz with knees flexing to over 20 Hz with rigid posture)
Biofeedback Is Based on Resonant Properties of the Cardiovascular System

§ Resonant frequency HR variability biofeedback gives people the ability to increase HR variability at a specific resonant frequency.

§ The biofeedback procedure produces high-amplitude oscillations in cardiovascular functions.
The Baroreflex Provides The Cardiovascular System with Resonant Properties

- If BP changes, the baroreflex produces contingent changes in HR and vascular tone (VT).
- The increases in BP produce decreases in HR and VT, and decreases in BP produce increases in HR and VT.
- By mechanical action increases in HR and in VT produce increases in BP, while BR-induced decreases in HR and in VT produce decreases in BP.
HR and BP Reactions to Stimuli if the Baroreflex Does Not Work

Blood Pressure

Delay~5 sec

Heart Rate

Stimuli

Gevirtz

1/7/2010
Stimuli elicit HR changes which, after a delay, change BP. BP changes, in turn elicit HR changes due to baroreflex activity.
HR and BP Oscillations Elicited by the Stimulus of Respiration

Blood Pressure

Delay ~ 5 sec

Heart Rate

Respiration

Time
Two Closed-Loop Baroreflex Model

Closed loop of HR baroreflex

Heart rate (HR) control system

W(HR-target) -> HR

Baroreceptors

Blood pressure (BP) control system

BP

W(BP-HR) -> BP

W(BP-HR) -> BP

BP

VT

Vascular tone (VT) control system

1/7/2010

Gevirtz
The highest HR oscillations are at a target frequency of ~ 0.1 Hz. The phase of HR and the stimulus (breathing?) at that frequency is ~ 0°.
Transfer function: Respiration to HRV

\((n = 6)\)

Vaschillo et al, *Chest*, in press
Transfer Functions of Blood Pressure with Regard to Heart Rate (Baroreflex Effect of BP) and HR with Regard to Stimulus

Max HR Oscil is at ~0.1 Hz (180° HR:BP Phase)

Min HR Oscil is at ~0.03 Hz (0° HR:BP Phase)
Therefore, HRV biofeedback stimulates the baroreflex

- Voluntary maximization of HRV requires people to breathe at their resonant frequency (~6/min)
- $180^\circ$ HR:BP phase relationship implies baroreflex (BR) stimulation
- BR and HRV are maximized
- BR is “exercised” and trained
- Neuroplasticity of the BR is demonstrated
Effects of Biofeedback Instruction to Increase HRV

- Slows breathing to resonant HRV frequency
- HRV and respiration are in phase
- HRV and blood pressure are $180^\circ$ out of phase
- Large increase in HRV at a single frequency
Resonant Frequency Varies Across Individuals

**Spectral LF Power (Subject 7311)**

- Spectral LF Power (ms²)
- Respiration Rate (breath/min)

**Spectral LF Power (Subject 7281)**

- Spectral LF Power (ms²)
- Respiration Rate (breath/min)

**R-R Intervals (Subject 7311)**

- RRI (ms)
- Respiration Rate (breath/min)

**R-R Intervals (Subject 7281)**

- RRI (ms)
- Respiration Rate (breath/min)
Examples of Individual Resonant Frequencies
## Individual Resonant Frequency (breath/min)

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Mean of the Resonant Frequency
(VERTICAL LINES PRESENT 1.98 STANDARD ERROR)

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<td>Women</td>
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<td>Men</td>
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P<0.0001
Regression of Height on Resonant Frequency

$r = -0.55$

$p < 0.0001$
The correlation coefficients (r) between resonant frequency and age, height, and weight:

- Age: $r = 0.01$, $P < 0.9$
- Height: $r = -0.6$, $P < 0.0001$
- Weight: $r = 0.02$, $P < 0.82$
Regression of Height by Resonant Frequency

$r = -.55$
Heart Rate Variability Amplitude at Reasonant Frequency

Asthma              Healthy

Beat/min

0 1 2 3

1/7/2010 Gevirtz 32
Conclusion

1) Each person has a specific resonant frequency.

2) The resonance frequency range is between 4.5 to 6.5 (times/min).

3) Asthma does not affect the resonant frequency.

4) Asthma decreases the amplitude of HR oscillation at the resonant frequency.
HRV biofeedback stimulates the baroreflex

- Voluntary maximization of HRV requires people to breathe at their resonant frequency (~6/min)
- 180° HR:BP phase relationship implies baroreflex (BR) stimulation
- BR and HRV are maximized
- BR is “exercised” and trained
- Neuroplasticity of the BR is demonstrated
Implications

- Baroreflexes are systematically stimulated with each breath, producing very high amplitude output.
- Does exercise improve baroreflex function?
- Voluntary increase in HRV (or BP variability?) requires breathing in phase with HR (BP) changes.
- Does phase with respiration improve breathing?
Heart Rate RSA Biofeedback Training: A Treatment Manual

Resonant Frequency (RFT) Training


Richard Gevirtz, Ph.D.

CSPP at AIU, San Diego, CA
Assessment

§ Using an EKG for the office procedure (Currently two are readily available: Thought Technology Infiniti or CardioPro and J&J Use 2, C-2 System), turn screen away from patient and allow at least 5 minutes of “free breathing”. It is useful to distract the patient by having them listen to an audio tape of neutral material (National Geographic, travelogs, etc)

§ RFT determination:

1. Instructions: (Show screen such as Fig. 1 or 2) “On this screen you will see your breath wave, your heart rate updated every beat, and a breath pacer. Try and breath at the pace of the pacer, but keep it as effortless as possible.”

2. Set pacer at 7, 6.5, 6, 5.5, 5, 4.5 breaths per minute. Use 2-3 minutes for each interval. Observe 1) peak valley differences in B/M, and LF power or relative power. Write down maximum values. For example, 24 B/M and .4 ms.

If you have a capnometer, watch for signs of HV
Fig. 1. J&J Screen showing HR, Resp, temp, Skin Cond, and a spectral analysis. Peak valley differences are about 14 B/M (79-65), LF is .1.
Fig. 2.1. CardioPro screen for HR and Resp

Heart Rate Variability

1 graph for heart rate or inter-beat interval (IBI)
Fig. 2.2. CardioPro Training Screen

Breath Pacer

Respiratory Sinus Arrhythmia

2D Spectrum graph of IBI with three frequency components
Treatment I

§ Once RF is determined, Use instructions such as the following: (from Lehrer, Vaschillo, and Vaschillo, p.184, italics mine)

§ Your heart goes up and down with your breathing. When you breathe in, your heart tends to go up. When you breathe out, your heart tends to go down. These changes in heart rate are called “Respiratory Sinus Arrhythmia” or RSA. RSA triggers very powerful reflexes in the body that help to control the whole autonomic nervous system (including your heart rate, blood pressure, and breathing). We will train you to increase the size of these heart rate changes. Increasing the size of these heart rate changes will exercise these important reflexes, and help them to control your body more efficiently. As a part of this treatment we will give you information about the swings in your heart rate that accompany breathing. That will be the RSA biofeedback. You will use this information to teach yourself to increase your RSA. If you practice the technique regularly at home, you will strengthen the reflexes that regulate the autonomic nervous system. This should help you manage your health (or IBS, or Pain, etc) and ability to manage every day stress.”
Treatment II

§ Training procedes:

§ EZ Air (BFE.org)(click on support)

- Use pacer or Breathsounds (www.BreathSounds.com) at first, but let the patient take over the pace when ready.

- Encourage home practice
  - Biosvyaz, St. Peterberg, Russia (www.biosvyaz.com)
  - Heart Math Freeze Framer(www.heartmath.com)
  - Heart Tracker (BioCom Technologies, www.biocomtech.com)
  - Temp monitor (about $20) available from BMI (or Future Health (www.futurehealth.org)
Bio-Medical Instruments (www.bio-medical.com)
Resp-e-Rate

Inner Tube/Somatic Visions

StressEraser/Helic or

Polar w/rr interval

Journey to the WildDivine/Healing Rhythms

Em Wave/ Heartmath
Treatment III

§ Check for RF peak and pattern at the beginning of each session with the screen hidden from the patient.

§ Once evidence for a good RF is found, challenge the patient with stressors and then instruct them to resume training.

§ Watch for VLF elevations. They represent either chronic sympathetic activation or vagal withdrawal (as in chronic worry).
Treatment Protocols

§ Build mediational model
§ Apply psycho-educational intervention
§ Use HRV biofeedback in conjunction with other therapeutic protocols
  † Examples: Pain, IBS, Asthma, Hypertension, Anxiety
Mediational Model of Psychophysiological Disorders

Early Developmental Factors

Cognitive/Emotional Factors

Physiological Systems

Physical Symptoms

“hysteria”

Genetics

Social & Cultural Factors

Factors

“hysteria”
Exemplar of mediational pathway to explain chronic muscle pain

Typical Diagnosis
- Cervical Strain
- Lumbar Strain
- Repetitive Strain Injury
- Tension Headache
- TMJ or TMD
- Myofascial Pain Syndrome

Typical Misdiagnoses
- Ruptured or bulged disc
- Pinched nerve
- Carpal tunnel syndrome
- Tennis elbow
- Bursitis
- Thoracic Outlet Syndrome
- Depression (or other Psychiatric diagnosis)
- Fibromyalgia
Needle EMG Activity

Trigger Point

Adjacent Non-Tender Muscle Fibers

Active Needle Electrode

Surface Reference Electrode

Active Needle Electrode
Effects of Curare on nEMG in TPs and Adjacent, (Non-tender) Sites

TP nEMG

Pre Injection Post

Adjacent nEMG
The Effect of Phentolamine Injection on TP & Adjacent nEMG

PHENTOLAMINE 2.5mg injected directly into trigger point in patient with myofascial pain
David Hubbard, MD, Dept Neurology, University of California, San Diego
Percent of Patients reporting taking narcotics for neck pain following a whiplash injury
Other Models I

§ Irritable Bowel Syndrome

- Prolonged Vagal Withdrawal
- 85% reduction in symptom following a biofeedback protocol to restore autonomic balance. Correlation ($r=.62$) between vagal tone increase and symptom reduction
  - (Sowder, Gevirtz, et al. 2008; Mayer, Naliboff et al., 2009)
Other Models II

Non-Cardiac Chest Pain

- Chronic hyperventilation and anxiety
- Breathing retraining reduced chest pain dramatically. Three year follow-up. Correlation between ETCO2 increase and symptom reduction ($r = .38$)
  - (DeGuire, Gevirtz, and Maguire, 1992, 1996)
Other models III

§ Fibromyalgia
  - Autonomic dysfunction
  - Stress enhanced hippocampal dopamanergic depletion
  - Improved sleep, pain reduction, etc.
    - (Martinez-Lavin, 2001; Wood et al., 2009)
Other models III

§ Fibromyalgia
   - Autonomic dysfunction
   - Stress enhanced hippocampal dopamanergic depletion
   - Improved sleep, pain reduction, etc.
     • (Martinez-Lavin, 2001; Wood et al., 2009)
COGNITIVE-BEHAVIORAL THERAPY FOR ADULT ANXIETY DISORDERS: A META-ANALYSIS OF RANDOMIZED PLACEBO-CONTROLLED TRIALS

Stefan G. Hofmann, Ph.D.¹ and Jasper A. J. Smits, Ph.D.²

¹Department of Psychology, Boston University, Boston, Massachusetts
²Department of Psychology, Southern Methodist University, Dallas, Texas
Effect size estimates (Hedges’ g) and the statistical tests of the acute treatment efficacy of CBT compared to placebo on the primary continuous anxiety measures for the identified studies.

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-4.00  | 0.00  | 4.00
Favors PLA  |  |  |  |
Favors CBT  |  |  |  |
Odds ratios and statistical tests of the acute treatment response to CBT versus placebo for the identified studies.
Tidal Volumes: #10, Control

Breath Number

Tidal Volume (mL)
Tidal Volumes: #56, Panic Disorder
$pCO_2$

Base 6 Fast Breathing / Rec FB

PD SP CON
The biological message of trauma

§ Remember this moment
§ Never go this way again
§ Be prepared

§ Severity defined by
  1. The breadth of the definition of “this way”
  1. The extent of the preparation
Deficit in awareness of internal sensations and being in the present

- Deficits in frontal sub-cortical circuitry and Cortico-thalamic integration  
  Vasterling et al., 1998; Clark et al. 2003

- Alexithymia  
  Krystal, 1988
    - Inability to accurately perceive internal states
Deficit in awareness of internal sensations and being in the present

§ Deficits in frontal sub-cortical circuitry and Cortico-thalamic integration Vasterling et al., 1998; Clark et al. 2003

§ Alexithymia Krystal, 1988
  - Inability to accurately perceive internal states
Evidence from neuro-imaging studies:

Exposure to trauma scripts produces:

- Increased activity (as measured by blood flow) in:
  - Right medial orbital frontal cortex
  - Insula
  - Amygdala
  - Anterior temporal pole

- Deactivation in:
  - Left anterior prefrontal cortex - especially Broca’s area (expressive speech)

Rauch, Van der Kolk, et al, 1996
Hull, 2002
Lanius, et al., 2001
Lindauer et al., 2004

Conditioned fear memories - the lateral nucleus of the amygdala to the central nucleus to the ANS; Amorapanth, La Doux, et al. 2000
“…when people are reminded of personal trauma they activate brain regions that support intense emotions, while decreasing activity in brain structures involved in the inhibition of emotions and the translation of experience into communicable language.”

(p.278)

Van Der Kolk, 2006
“…when people are reminded of personal trauma they activate brain regions that support intense emotions, while decreasing activity in brain structures involved in the inhibition of emotions and the translation of experience into communicable language.”

(p.278)

Van Der Kolk, 2006
Figure 1: Emotion Dysregulation in PTSD

**Emotional Undermodulation**
- Reexperiencing

**Emotional Overmodulation**
- Dissociation

Regions implicated in regulation of emotion and arousal

Regions implicated in regulation of emotion and arousal

Regions implicated in regulation of emotion and arousal
PTSD Biological Evidence

Neuropsychological Alterations (Charney, et al., 1993; Kolb, 1987; van der Kolk, 2006)

- Excessive emotional stimulation alters neurological functioning
- PTSD symptoms are maladaptive neurobiologic sequelae

Low cortisol (Yehuda, Boisoneau, Mason, & Giller, 1993; Yehuda, Kahana, Binder-Brynes K & Southwick, 1995)

- Paradoxical: Stress = Surge of cortisol
- Cortisol inhibits, stabilizes stress hormones

Autonomic Nervous System

- Elevated HR (Buckley and Kaloupek, 2001; Keane et al., 1998)
- Low HRV (autonomic dysregulation) (Cohen, Kotler, Matar, & Kaplan, 1997; Cohen, et al, 1998; Hopper, Spinazzola, Simpson, & van der Kolk, 2006; Sack et al., 2004; Sahar, Shalev, & Porges, 2001)
PTSD: Evidence of Underlying Biological Core?

PTSD is Psychophysiological Disorder:

Universal symptom: **intrusive memories: not event itself** > unique

- Intrusion > hyperarousal > insomnia > hypervigilance > exaggerated startle response

- Longitudinal study (Schell, Grant, and Jaycox, 2004)
  - Severity of the hyperarousal cluster leads to greater symptom severity of intrusion + avoidance cluster (12-months).
  - Converse is not true.
John Hughlings Jackson to MacLean:
Devolution to Triune brain structure

- Organization of the CNS-”bottom up”
- Executive functions (prefrontal cortex) under ordinary circumstances can inhibit, organize, and modify automatic processes coming from the lower centers
- “…the higher nervous arrangements inhibit (or control) the lower, and thus, when the higher are suddenly rendered functionless, the lower rise in activity.” J.H. Jackson in Taylor, 1958
- Elaborated in the 1990 by Mac Lean’s concept of the Triune brain
Why include HRV training: 1

As Foa et al. (2002) point out, a minority of patients in PE show a reliable increase in symptoms

- 21.1% exacerbation of anxiety symptoms
- 10.5% increase in PTSD symptoms
- Exacerbation doesn’t mean dropout or poor outcome.

The average dropout rate in CT or PT is 20-30%.

Therefore there is some evidence that management of the anxiety of treatment is a problem in current treatment.
Why include HRV training

§ Both alexithymia and dissociation are highly comorbid with PTSD.

§ Therefore one cannot count on the patient being able to reliably describe their internal state of anxiety during PTSD treatment.
Why include HRV training: 3

§ Hyperventilation and Hyperventilation syndrome are comorbid with PTSD (particularly PTSD with panic)

§ The experience of hyperventilation syndrome mimics anxiety and dissociative syndromes

§ Hyperventilation syndrome is curable with high success rates by HRV training.
Applications II: New ideas and challenges

In addition to affecting autonomic homeostasis, it is possible that the HRV biofeedback technique can affect:

- Mood/Dysphoria
- Anxiety
- Immune and inflammatory systems
- Limbic emotional regulation (mindfulness)
Treatment success over time
Developmental perspective

§ Human species unique in their flexibility; ability to make choices of how to respond, but these functions develop slowly

§ Higher function develop during childhood and don’t exist in final form until young adulthood

§ Vagal development, especially the “smart vagus” follows this developmental sequence

§ “The rational mind, while able to organize feelings and impulses, does not seem to be able to abolish emotions, thoughts, and impulses.” Van der Kolk, 2006, p.279
Tracey et al. have postulated that a vagally mediated system might be powerfully involved in regulating anti-inflammatory responses in the short term for benefit, but over time producing detrimental effects.
Cytokine theory of disease (Tracey, 2007)

Disease
- Shock
- Organ failure
- Tissue damage
- Arthritis
- Psoriasis
- Ileus
- Colitis

Health
- Depression
- Fever
- Anorexia
- Pain
- Edema
- Leukocyte recruitment
- Antibacterial activity
- DC maturation

Physiological manifestation
Other Treatment or Performance Protocols?

§ Questions???