Heart Rate Variability Biofeedback

Friday, June 11, 1:00pm – 5:00pm
Saturday, June 12, 9:00am – 4:00pm

Continuing Education:
The Association for Applied Psychophysiology and Biofeedback is approved by the American Psychological Association to offer continuing education for psychologists. AAPB maintains responsibility for the program. CE certificates will be emailed to those that complete the online evaluation.

This workshop is eligible for 9 credits.
SCHEDULE OF EVENTS:

Friday, June 11, 2010

1:00pm - 1:15pm Welcome and Introductions

1:15pm - 1:30pm HRV Biofeedback: what it looks like, what it is good for, and how it works (general overview)

1:30pm - 2:30pm Heart Rate Variability: what it tells us about the autonomic nervous system, health, and self regulation

2:30pm - 3:00pm Effects of HRV biofeedback on autonomic nervous system function

3:00pm - 3:15pm Break

3:15pm - 5:00pm The mechanism for HRV biofeedback: resonance in the cardiovascular system

Saturday, June 12, 2010

9:00am - 10:00am Clinical effects of HRV biofeedback

10:00am - 11:00am Case material

11:00am - 11:30am Break

11:30am - 12:30pm A protocol for teaching HRV biofeedback

12:30pm - 1:30pm Lunch

1:30pm - 4:00pm Supervised practice of HRV biofeedback: finding your own resonance frequency and that of others
Heart Rate Variability Biofeedback: Effects on Cardiovascular and Baroreflex Function

Inherently interdisciplinary (and international) nature of this work: my collaborators

- Psychologists
  - Stephen Porges, PhD
  - Maria Karavidas, PsyD
  - Richard Carr, PsyD
  - Jonathan Feldman, PhD
  - Nicholas Giardino, PhD
  - Yoshihiro Saito, PhD
  - Japan
  - Susan Isenberg, PhD
  - Omer Van den Bergh, PhD
  - Belgium
  - Richard Gevirtz, PhD
  - Michael Gara, PhD
  - Alfon Hassett, PhD

- Physiologists
  - Robert Edelberg, PhD
  - Evgeny Vaschillo, PhD
  - Alexander Smetankine, PhD
  - Russia

- Physicist
  - Tom Kuusela, PhD
  - Finland

My Collaborators (cont’d)

- Biomedical engineers
  - William Craelius, PhD
  - Robert Habib, PhD
  - Andrew Jackson, PhD
  - Jan Hoover, MA

- Aeronautical engineers
  - Archie Dillard, PhD

- Nurses
  - Annabaker Garber, PhD
  - Susette Coyle, RN

- Statisticians
  - Shou-En Lu, PhD
  - Regina Liu, PhD
  - En-Young Mun, PhD
  - Andrew Cheng, PhD

- Surgeons
  - Stephen Lowry, MD

- Cardiologists
  - Dwain Eckberg, MD

- Pulmonologists
  - Stuart Gordan, MD
  - Michael Goldman, MD

- Psychiatrists
  - Frederick Wamboldt, MD
  - Yuji Sasaki, MD, PhD
  - Javier Escobar, MD

- Neurologist
  - O. Leo Oikawa
  - Japan

- Topica

  • TODAY
    1. Stress, regulation, dysregulation, regulatory systems
    2. The meaning of heart rate variability: what it represents in the body. Autonomic pathways and as a representation of general adaptability
    3. Heart rate variability biofeedback
      a. The history of the method
      b. Physiological effects
      c. The concept of “resonance” and how it explains HRV biofeedback effects

  • TOMORROW
    1. Outcome research with HRV biofeedback: applications to respiratory, emotional, cardiovascular, gastrointestinal, and psychoneurological diseases and disorders; applications to sports and peak performance
    2. Protocol for doing it
    3. Find your own resonance frequency

Disclosure (my philosophy)

- All emotional problems involve psychophysiological as well as cognitive and behavioral components.
- Although most practitioners of cognitive behavior therapy are familiar with at least one relaxation technique, few are knowledgeable about the wideranging effects of relaxation and biofeedback methods.
- New technologies make these methods inexpensive and simple to use.
- Psychophysiological components that are often ignored when this component of psychotherapy is left out, often to the clients’ detriment.

Disclosure 2

- This talk will describe two simple and inexpensive methods: progressive muscle relaxation (with and without surface EMG biofeedback) and heart rate variability biofeedback.
- I have incorporated these techniques in my standard CBT practice, and have done research with them for over 30 years.
- I will describe some of this research and clinical experience.
- I am not sponsored by any commercial entity, and receive no financial benefit from the wider use of these methods.
Additional disciplines of others doing research in HRV biofeedback

- Gastroenterology
- Hypertension / nephrology
- Otolaryngology
- Optometry / ophthalmology
- Dentistry
- Maybe a few more

A MODEL OF STRESS AND FUNCTION

- Adaptation
  - Flexibility
- Oscillation and variability
- Noise
- Chaos and limit system

Measurement of R-Wave

- The time between R-wave peaks is interbeat interval or heart period. It is also called "NN" (normal to normal) interval.

Normal Heart Rate Variability (HRV) at Rest

HRV Healthy Subjects at Rest
Example of High Level of RSA

Notice how heart rate increases with inhale. Heart rate decreases with exhale. This pattern shows high vagal tone (high PSNS activity) and a high amount of heart rate variability.

Example of Low Level of RSA

Here’s an example of a lower RSA and less heart rate variability, either due to less vagal (PSNS) activity or increased sympathetic activity. Note less heart rate variation and it is poorly related to respiration.

HRV Biofeedback Effects on HR

Characteristics: High total amplitude all at at single frequency,

64 year old woman with anxiety, depression, and chronic cough

HRV BIOFEEDBACK EFFECTS

• Primarily affects the parasympathetic nervous system
• Strengthens regulation; targets dysregulation
  – Targets autonomic balance
  – Strengthens the baroreflex (a homeostatic reflex)
  – Targets respiratory regulation / interaction with respiration
  • Increases oscillations
  • Phase relationships interact with other processes
    – Blood pressure regulation
    – Respiratory regulation
    – Emotional regulation
• New theoretical applications to the sympathetic system
• Mostly voluntary sympathetic control is now best achieved through muscle control
The Problems of the Psychophysiologist

Oscillation as noise

Normal Heart Rate Variability (HRV) at Rest

Mother’s Emotion: Total Spectrum Variability vs. Positivity

\[ N = 60, r = .55, p < .0001 \]

Children’s Emotion: Total Spectrum Variability vs. Positivity

\[ N = 60, r = .09, p = \text{n.s.} \]

- Dysregulation

"I told you, Mamma, the blood keeps going to my head."

Good Regulation
Computer-Generated “HRV”

Stress Effects

- Fight –flight reaction
- Parasympathetic stress reactions
  - Blood phobia
  - Asthma – individual response stereotypy
- Regulation reflected in oscillations, various regulatory reflexes, balance among systems, appropriateness for situation and for health
- Dysregulation and ‘allostatic load’

Allostasis (McEwen)

- literally “maintaining stability or homeostasis through changes”
- the process of adaptation to acute stress, involving the output of stress hormones which act to restore homeostasis in the fact of a stressful challenge

WHEN YOU ARE STRESSED THE AUTONOMIC NERVOUS SYSTEM GOES INTO ACTION IN TWO WAYS

- It gears you up to do things --- it sends blood and nourishment to the parts of the body that need it to do the things you need to do
- It acts to protect your body from too much “gearing up” – to REGULATE the body, so JUST THE RIGHT AMOUNT of activation takes place

GEARING UP TO DO THINGS

- Think faster (brain blood flow)
- Move around (muscle tension and higher heart rate and blood pressure)
- Nourishment – put out blood sugar
- Breathe more, dilate the lung
- See things better (blink less) or protect eyes (blink more)
- Less digestive activity
- This is the “ACTIVE COPING” pattern: the autonomic nervous system gears you up to do, accomplish, handle things

Allostatic (Over)load

- Poor functioning in tasks
- Deterioration in health
- Body no longer can preserve homeostatic balance
- Applies to all systems
  - Respiratory, cardiovascular, digestive,
  - Behavioral (instrumental/hedonic/relaxation/nourishment)
  - Social system (instrumental/affective)
Body as a Control System

- Adaptation
  - Flexibility
  - Normal cardiovascular variability
- Homeostasis
- Oscillation
  - Oscillation is related to control and regulation; may model homeostatic process
- Chaos and limit system
  - Complexity is related to multiplicity of processes

Oscillation and Health

- HRV and health
- Emotional Positivity and Variability
- Immune system (white blood cell)

Premenstrual Dysphoria

- Daily self-ratings of sadness 50-120 days
- Patients with PMDD show more regularity (smaller Approximate Entropy) than healthy women

Major Depressive Disorder

- $N = 16$ with major depression, 10 healthy, age and sex matched
- Decreased circadian variation during depression
  - motor activity
  - body temperature
  - urinary potassium


Somatic interventions (other than drugs)

- Muscle relaxation (tied to sympathetic system)
- Self-hypnosis, autogenic training (tied to cognitive mediation)
- Slow breathing/HRV biofeedback (tied to parasympathetic system and homeostatic control)

RESPIRATION AND MUSCLE TENSION AS PART OF THE STRESS RESPONSE: WE CAN EASILY LEARN TO CONTROL THESE

Muscles and sympathetic nervous system

- Muscle feedback and arousal:
  - muscle tension increases sympathetic arousal and vice versa
- Anxiety and stress are almost always accompanied by elevated muscle tension

Muscles and sympathetic nervous system

- Muscle feedback and arousal:
  - muscle tension increases sympathetic arousal and vice versa
- Anxiety and stress are almost always accompanied by elevated muscle tension (measured from muscle spindle)
  - (mental arithmetic stress)

The Muscles and the Mind

- McGuigan’s cognitive research
  - Verbal thought involves the muscles
  - Visual thought involves the muscles
  - Kinesthetic imagination involves the muscles
  - Hallucinations involve the muscles

Other Correlates of Muscular Activity

- Individual differences
  - Athletics: Vaschillo
    - Relaxation time correlates with athletic ability
  - Jacobson’s research
    - Relaxation time: athletes < “person on the street” < patients with anxiety and tension symptoms
Progressive Muscle Relaxation

- Teach profound control over muscle tension
- Thereby decrease sympathetic arousal and psychophysiological reactivity
- Treat tension-related diseases
  - Almost all diseases have tension components
- Even *thinking* is related to muscle activity

Some Applications of PMR

- Irritable bowel syndrome
- Hypertension
- Anxiety disorders
- Headache
- Everyday stress
- Insomnia

Functions of Respiration

- Oxygenation
- As a physiological oscillator
- Musculoskeletal effects
- Mental effects
- Adaptation to environmental need: activation of other systems
  - Respiration and attention (demonstrate)
Subject 005. Landing 6 (Landing with one landing gear stuck up)
HR rose to 136 bpm, & hyperventilation (ETCO2 < 32 mmHg) lasted for 300s.
Functions of Sighing

- Resets parasympathetic function
  - Sleep study in infants
- Regulates CO2 balance and perhaps other respiratory functions
- Adjusts neural control of breathing
- When dysregulated it can induce hyperventilation

Panic and Hyperventilation

- PD patients tend to hyperventilate chronically
- Hyperventilation does not reach clinical levels (<32 mm Hg ET CO2) until stimulated, or during a sigh

(Wilhelm, Trabert, & Roth, 2001)

PD Patients tend to breathe more irregularly (ie, sigh more)

Autocorrelation of consecutive tidal volumes

Respiratory Impedance

(Papp et al, 1997)
Panic Disorder Patient

Resonance Frequency Breathing and Hyperventilation

Respiration can Interact with Autonomic Effects of Stress

Respiratory control in stress reduction
WHEN YOU ARE STRESSED
THE AUTONOMIC NERVOUS SYSTEM GOES INTO ACTION IN TWO WAYS
• It gears you up to do things --- it sends blood and nourishment to the parts of the body that need it to do the things you need to do
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Body as a Control System
• Adaptation
  – Flexibility
  – Normal cardiovascular variability
• Homeostasis
• Oscillation
  – Oscillation is related to control and regulation; may model homeostatic process
• Chaos and limit system
  – Complexity is related to multiplicity of processes

Examples of Stress-Related Parasympathetic Reactions
• Healthy and Chronic Fatigue Syndrome patients exposed to noxious diesel odors
  • (Fiedler et al)
• Defensive and nondefensive asthma patients and healthy subjects
  • (Feldman et al)

Polyvagal theory
Stephen Porges, Ph.D
• Porges has suggested that high levels of tonic vagal input from the nucleus ambiguous promotes health, growth and restoration in the viscera
• High vagal tone is associated with the ability to self-regulate and thus have greater behavioral flexibility and adaptability
• HRV quantifies the relative contributions of both the sympathetic and parasympathetic branches. It is established in the literature that the parasympathetic branch, or vagal tone, influences HRV and HR independently of the sympathetic branch (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

• Higher vagal tone promotes autonomic homeostasis (Porges, 1995) and appropriate emotional responsivity (see Porges, Doussard, & Maiti, 1994 for a review).

The Conventional View:
Heart Rate Variability as a Reflection of Parasympathetic Balance

Computer-Generated “HRV”
RESPIRATION AND MUSCLE TENSION AS MEDIATORS OF BEHAVIORAL EFFECTS ON THE BODY

High Frequency (15 - .4 Hz): RSA, vagally mediated, "vagal tone(?)", "vagal modulatory activity"(?)

Low Frequency (04-. 15 Hz): Both sympathetic and parasympathetic regulation, baroreflex control(?)

Very Low Frequency (003-. 04 Hz): Sympathetic mediation, thermal regulation(?)

Ultra Low Frequency (<.003 Hz) Alertness(?)
Alternative Ranges

ULF: <.005 Hz
VLF: .005-.05 Hz
LF: .05-.15 Hz
HF: .15-.4 Hz


HRV and adaptability

- High HRV
  - Health
  - Youth
  - Aerobic fitness
  - Survival

- Low HRV
  - Illness
  - Older age
  - Poor aerobic fitness
  - Death
  - Stress
  - Depression/anxiety

Confusion: Two Ways of Viewing HR Variability

- A reflection of vagal tone and/or autonomic balance
- A reflection of homeostatic capacity
- Partially consistent if we give up the notions of
  - Stress is “bad” for us, low “activation” is a desirable state
  - The physiology of stress = the “fight-flight reaction”
  - HRV reflects only sympathetic/parasympathetic balance
  - Changes in HRV necessarily reflect changes in parasympathetic control

Example of Spectral Activity

Here is the spectral activity, showing activity across frequencies. This can reveal information about relative contributions of SNS and PSNS activity.

RSA and VAGAL TONE

- RSA SOMETIMES REFLECTS VAGAL TONE
  - Drug effects
  - Task reactivity
  - Defensiveness
    - The special case of asthma
    - Solution: look at HR too

Characteristics of RSA (HF variability) During Stress

- RSA depressed and HR elevated in panic group (more on this later)
- RSA depressed and HR elevated during mental arithmetic
- RSA elevated and HR low during surgery film

- Vagal suppression?
- Vagal activation?
- An example of stress-related vagal activation?
- Note: panic patients do not show HR decrease
Oscillation Frequencies and Autonomic Balance

(Task force of European Society of Cardiology and the North American Society of Pacing & Electrophysiology, Circulation, 1996)

**High Frequency (15 - 4 Hz):** RSA, vagally mediated, "vagal tone(?)", "vagal modulatory activity(?)")

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**Very Low Frequency (003 - 04 Hz):** Sympathetic mediation, thermal regulation(?)

**Ultra Low Frequency (<.003 Hz):** Alertness(?)

Alternative Ranges

ULF: <.005 Hz ??? (renin angiotensin system???)

VLF: .005-.05 Hz (blood pressure control through vascular changes, vascular baroreflex, thermal regulation, alpha sympathetic control)

LF: .05-.15 Hz (blood pressure control through heart rate changes, HR baroreflex, mostly parasympathetic but perhaps also beta sympathetic effects)

HF: .15-.4 Hz (respiratory sinus arrhythmia, parasympathetic control, affects gas exchange)

Confusion: Two Ways of Viewing HR Variability

- A reflection of vagal tone and/or autonomic balance
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**HRV and Adaptability**
(conclusions from 1000’s of studies)

- **HIGH HRV**
  - Youth
  - Aerobic fitness
  - Health
  - Survival

- **LOW HRV**
  - Death
  - Disease
  - Stress
  - Inflammation

**Respiratory Sinus Arrhythmia**

- HR oscillations linked to breathing
- Parasympathetically mediated
- Vagus nerve blocked during inhalation, stimulated during exhalation
- Usually 90 degrees out of phase with respiration
- Related to gas exchange efficiency
- Under central control as well as control by respiration
- Occurs in a particular frequency range (i.e., the range at which people usually breathe) .15-.4 Hz, or 9-24 / min

**Function of Respiratory Sinus Arrhythmia**

- Yasuma & Hayano (2004): promotes respiratory efficiency
- HR increases during inhalation
- More blood to alveoli when O₂ concentration is highest

**“Artificial RSA” Study**

(Hayano et al., 1996) (Electrical stimulation of HRV and respiration in 7 denervated dogs)

VD = Vital dead space; VT = tidal volume, QSP = O₂ concentration (Alveolar - Arterial)
QT = O₂ concentration (Alveolar - Venous)

**RSA and VAGAL TONE**

- RSA SOMETIME REFLECTS VAGAL TONE
  - Drug effects
  - Task reactivity
  - Defensiveness
    - The special case of asthma
  - Solution: look at HR too

**Respiratory Sinus Arrhythmia**

- No differences in: RR, VT, QT, HR, BP
Demonstration of artificial physical strain on the system

- Effects of exposure to inflammatory cytokines
- Decrease in HRV across the board (possible short-term rebound in LF), increase in HR
- General autonomic withdrawal, and withdrawal of regulation

Demonstration of parasympathetic rebound from relaxation

- Countertherapeutic for asthma, even where stress reduction is mildly helpful in the long run
Physiological Changes During Relaxation in Asthma

Spirometry Changes During Relaxation Therapy for Asthma

SUMMARY

- HRV biofeedback improves adaptation
- Adverse stress effects reflect allostatic overload
- Adaptive systems can be modeled as oscillatory systems
- The problem isn’t just sympathetic overactivity or parasympathetic underactivity. It is dysregulation
- Next section: HRV is an oscillatory system, targeting homeostatic reflexes, affected by HRV biofeedback
Pilot Study Strain Gauge

Low Frequency HR Variability (.03-.12 Hz)

First & Fourth Sessions

Frequency Analysis of HRV Across RSA Biofeedback Training Sessions

Hyperventilation & RSA Biofeedback
**Low Frequency R-R Interval of EKG**
(5 min periods during 1st, 4th, 7th, and 10th biofeedback sessions)

**Mean R-R Interval**

**Total RRI power**

**Baroreflex Gain (low frequency band)**

**High Frequency RRI power**

**Mean Diastolic BP**
Function of Respiratory Sinus Arrhythmia

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"Artificial RSA" Study
(Hayano et al., 1996) (Electrical stimulation of HRV and respiration in 7 denervated dogs)

- No differences in: RR, VT, Qt, HR, BP
- VD = Vital dead space; VT = tidal volume,
  QSP = O₂ concentration (Alveolar - Arterial)
  QT = O₂ concentration (Alveolar - Venous)

BUT 0° phase relationship in intact humans occurs only during resonant-frequency breathing

L. Bernardi’s research: 6/min breathing

- Increases tolerance to lower SaO₂
- Increases respiratory gas exchange efficiency
- Decreases dyspnea
- Greater resistance to hyperventilation
- Lowers hypoxic ventilatory response
- Increases baroreflex response in chronic heart failure

Yogis and Sherpas Breathe at This Rate and Tolerate Altitude

- Low hypoxic ventilatory response in laboratory
- Resist hyperventilation
- Higher SaO₂
- Low hemoglobin
- Low minute volume ventilation
- No mountain sickness
- High exercise tolerance
Slow breathing may increase serotonin
Slow breathing 3-4/min, produces decreased anxiety and more energy, as well as increased HRV (↑ sympathetic [VLF] activity, vascular tone resonance)


42 year old Zen Rinzai Master, Resting

70 year old zen monk during tandem breathing

70 year old Zen Rinzai Master, Resting

42 year old Zen Rinzai master during Tanden Breathing

70 Year Old Zen monk at rest

32 Year Old Zen Rinzai nun during Tanden Breathing

32 Year Old Zen Rinzai nun during Tanden Breathing
Inflammatory System Effects?

- cholinergic neurons inhibit acute inflammation

Inflammatory Effects

- vagus nerve stimulation attenuates the systemic inflammatory response to endotoxin

Procedure

- Healthy participants (n=11) experimentally exposed to lipopolysaccharide (LPS)
- Prior to acute inpatient phase with LPS exposure, four one hour training sessions of either
  - HRV BF (breathing at resonant frequency; about 6/min) or
  - control condition (15/min)
- Participants coached to do the paced breathing at hourly timepoints after LPS injection
Log LF HRV (Task A)

Log ms

Heart Rate

Respiration Rate (Task A)

Significant Symptom Effects

Nonsignificant Symptom Effects

Group and Group x Hour n.s.

Control

Biofeedback

Headache

Biofeedback

Placebo

Eye Sensitivity to Light
**Resonances in the Cardiovascular System**

HRV biofeedback is based on resonance properties of the CVS.

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**Resonance in a System**

**Resonance** is a phenomenon characterized by the appearance of oscillations in a system at a specific frequency (resonance frequency) in response to perturbation.

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There are two kinds of systems:

- Aperiodic systems
  - and
- Resonance systems

Each one has a specific response to stimuli.

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**Reaction of Aperiodic and Resonance Systems to Stimulus**

<table>
<thead>
<tr>
<th>Perturbation Stimulus</th>
<th>Resonance frequency: $F[Hz] = 1/T[s]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Time</td>
</tr>
</tbody>
</table>

A system has resonance properties (i.e., becomes a resonance system) when two processes (functions) in the system interact with each other with a delay.

For example: a simple pendulum.

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**Pendulum as a Resonance System**

A pendulum can oscillate because kinetic and potential energies of its mass interact with each other through feedback.

Kinetic energy transforms into potential energy and vice versa.
The Human Body Includes Many Resonance Systems

To understand why human beings are more sensitive to some frequencies than others, it is useful to consider that the human body has sub-systems, and each sub-system has its own resonance frequency.

The Cardiovascular System Also Has Resonance Properties

- Resonances in the cardiovascular system (CVS) are manifested by high-amplitude oscillations in autonomic functions at frequencies of \(~ 0.1 \text{ Hz} \) and \(~ 0.03 \text{ Hz} \).
- Resonance properties of the CVS are based on baroreflex activity.

The Baroreflex Provides Resonance Properties in the CVS

- The baroreflex, like any other reflexes, may be considered as a closed-loop control system with feedback.
- Such systems reveal resonance properties if a delay is present in the closed-loop.
- The value of the delay determines the value of resonance frequency.

The Baroreflex Provides the CVS with Resonance Properties

- If BP changes, the baroreflex produces contingent changes in HR and vascular tone (VT) to eliminate shift in BP.
- Increases in BP produce decreases in HR and VT, while decreases in BP produce increases in HR and VT.
HR and BP Reactions to Stimulus if the Baroreflex Does Not Work
A short stimulus (e.g., an inhalation) elicits a HR increase, which slowly returns to its previous state. Due to inertia in blood mass, BP responses to HR increases will be delayed for 5 s. The stimulus does not elicit oscillation in the system. This is an aperiodic system.

HR and BP Oscillations Elicited by Rhythmical Stimulation at Resonance Frequency
Rhythmical stimulation at RF elicits high-amplitude HR and BP oscillations because at RF respiration and HR oscillations are in phase (0°); HR and BP oscillations are in contra phase (180°).

We found that 0.1 Hz CVS (HR) resonance can be effectively stimulated by:
- Breathing at a frequency of ~0.1 Hz
- Rhythmical (0.1 Hz) presentation of emotionally valenced pictures
- Rhythmical (0.1 Hz) muscle tension
- Rhythmical (0.1 Hz) pressure of the brachial artery with a cuff.

HR and BP Reactions to Stimuli if the Baroreflex Works (Explanatory model)
A stimulus elicits HR increase which subsequently increases BP after a 5-s delay. The BP increases trigger the baroreflex, which immediately elicits decreases in HR. After a 5-s delay, the decreases in HR elicit decreases in BP, which, in turn, increase HR via the baroreflex. Thus, 0.1-Hz oscillations occur in the system. This is a resonance system.

Due to resonance, rhythmical stimulation of the CVS at resonance frequency elicits stable high-amplitude oscillations in CVS functions.

Breathing at a Frequency of ~0.1 Hz and HRV Biofeedback
HRV Biofeedback is Based on Resonance Properties of the CVS

- The HRV biofeedback procedure produces high-amplitude oscillations in cardiovascular functions at the resonance frequency of ~0.1 Hz.
- Resonance makes it possible to produce these oscillations voluntarily.

Cardiovascular functions oscillation during the HRV biofeedback procedure

Using HRV biofeedback, subjects induced high amplitude oscillations in HR. The procedure also elicited high amplitude blood pressure and vascular tone (VT) oscillations at the same frequency.

(Real record)

Study of 0.1-Hz Resonance in CVS

Fifty-six subjects: 24 healthy volunteers and 32 asthma patients participated in the study.

Defining Individual Resonance Frequency:

- Each person performed five 2-minute tasks.
- The person was asked to breathe following a pacer.
- The pacer rate was sequentially set at 6.5; 6.0; 5.5; 5.0; 4.5 times/minute.
- HRV frequency spectra were calculated for each task.
- Peak amplitude for each tested frequency was measured.
**Mean of the Resonance Frequency**

(Vertical lines present 1.98 standard error)

<table>
<thead>
<tr>
<th></th>
<th>All subjects</th>
<th>Asthma</th>
<th>Healthy</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonance Frequency</td>
<td>5.53 ± 0.47</td>
<td>5.53 ± 0.47</td>
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**Correlation coefficients (r) between resonance frequency and age, height, and weight**

- **Age**
  \[ r = -0.60, \quad p < 0.0001 \]

- **Height**
  \[ r = 0.01, \quad p < 0.9 \]

- **Weight**
  \[ r = 0.02, \quad p < 0.8 \]

**We have found:**

- Each person's cardiovascular system had resonance properties.
- The frequency at which HRV resonance occurred differed among individuals within the frequency range (4.5-6.5 times/min).
- The mean HRV resonance frequency (m ± sd) was 5.53 ± 0.47 times/min.
- Each individual's HRV resonance frequency was stable for at least 3 months.


**We have found**

- The average of resonance frequencies did not differ between asthmatic and healthy individuals, and was not related to age or weight.
- The resonance frequencies were higher in women than in men, and were linearly inversely related to the height (very significant).

**We have found**

- Asthma did not affect resonance frequency.
- Asthma decreased the amplitude of HRV oscillation at the resonance frequency.

**CONCLUSION**

Respiration at resonance frequency elicits the highest oscillations in CVS.

We hypothesized (Lehrer et al., 2003) that HRV biofeedback provides therapeutic effects because these oscillations train and improve autonomic reflexes.

In order to apply HRV biofeedback effectively in the treatment, each individual’s resonance frequency should be defined.

**Rhythmical (0.1 Hz) Presentation of Emotionally Valenced Pictures**

Assessment of the Cardiovascular System Reaction to Picture Presentation

Resonance Approach

**Using variability of the cardiovascular functions to evaluate emotions**

- CVS actively participates in emotion regulation.
- To estimate the strength of emotion to picture block presentation, reactions of HR, VT, and SC variability were applied in our study.
- Resonance property of the CVS (based on 0.1 Hz resonance) was used to maximize the sensitivity of response to rhythmical stimulation at the same frequency.
The Resonance Approach We Applied Gave Us the Opportunity to:

- Amplify cardiovascular reaction to the IAPS picture cues.
- Enhance sensitivity of physiological measurements by using a new 0.1-Hz HRV index to evaluate the strength of emotions.
- Consider rhythmical picture stimulation as a therapeutic procedure to restore excitation-inhibition balance in the central and autonomic nervous systems, and to train and tone autonomic reflexes.

**Potential Clinical Applications of Rhythmical Picture Presentation**

**High-amplitude Oscillations**
elicted by visual stimulation as well as oscillations from paced breathing or paced muscle tension may be useful for the treatment of disorders.

An advantage of picture cue stimulation is that content of the stimuli can be easily manipulated.

**Rhythical (0.1 Hz) Skeletal Muscle Tension Technique**

High-amplitude Oscillations in Cardiovascular Functions
Rhythmical Skeletal Muscle Rhythmical Skeletal Muscle Tension (RSMT) Procedure at Frequency of 0.1 Hz

Participants performed repeated alterations: 5 s muscle tension - 5 s muscle relaxation.

We found that this procedure elicits High-amplitude Oscillation in Heart Rate, Blood Pressure, and Vascular tone.

**HR Reaction to 0.1 Hz Rhythmical Muscle Tension**
The procedure imposed high-amplitude 0.1 Hz oscillation (30-35 bpm) on HR.

**Systolic Blood Pressure Reaction to 0.1 Hz Rhythmical Muscle Tension**
The procedure imposed high-amplitude 0.1 Hz oscillation (40-45 mmHg) on blood pressure.
Pulse Transit Time Reaction to 0.1 Hz Rhythmical Muscle Tension
The procedure imposed high-amplitude 0.1 Hz oscillation (30-35 ms) on pulse transit time.

Clinical Application of Rhythmical Skeletal Muscle Tension Procedures
RSMT procedures at a frequency of 0.1 Hz successfully avert vasovagal reactions (France et al., 2005, 2006).

Vasovagal reaction is characterized by sudden fainting that can be triggered by pain, fear, trauma, or happens without apparent cause.

Why Does the RSMT Procedure Produce Therapeutic Effects?

Therapeutic effects of the RSMT Procedure can be explained by training autonomic reflexes and restoring sympathovagal balance due to resonant High-amplitude Oscillations.

Potential Clinical Applications of the RSMT Techniques
Rhythmical physical exercises at 0.1 Hz may prove especially useful in the rehabilitation process of patients following a cerebral stroke and myocardial infarction, in treatments where physical exercises are prescribed (Buch, Coote, & Townend, 2002), or in sports medicine.

We compared HR reactions to rhythmical muscle tension at frequencies:
- 0.2 Hz (oscillation period 5 s)
- 0.1 Hz (oscillation period 10 s)
- 0.05 Hz (oscillation period 20 s)
Rhythmical (0.1 Hz) Vascular Tone Stimulation

Heart Rate Response to:
- 0.1 Hz vascular tone stimulation
- 6 times per minute breathing

0.1 Hz VT stimulation elicited high-amplitude HR oscillation at 0.1 Hz but 6 times per minute breathing elicited 1.5 times higher HR oscillation.

Pulse Transit Time (Vascular Tone) Response to:
- 0.1 Hz vascular tone stimulation
- 6 times per minute breathing

0.1 Hz VT stimulation elicited high 0.1 Hz oscillation in PTT while 6 times/min breathing caused a 0.1 Hz PTT oscillation 1.5 times lower.

~0.03 Hz CVS resonance can be effectively stimulated by:
- Strong aversive sounds as stimuli
- Strong emotionally valenced stimuli

(0.03 Hz - period of oscillation 33 s)

Reaction of resonance system to stimulus

HR reaction to sound “Theta” at 82 dB

Extremum 1: 83.5 bpm
Extremum 2: 56.6 bpm
Heart Rate Reaction to Sound ID “Delta” at 92 dB

HR reaction to aversive sounds

Heart Rate Reaction to Sound

Emotionally Valenced Pictures
Triggered 0.03 Hz Resonance in Cardiovascular System

An Example of the 0.03 Hz Resonance in the CVS:

HR Reaction to Negative Pictures.

Conclusion

- Resonance properties of physiological systems appeared to be useful for medical practice.
- Resonance offers the opportunity to create simple, clinically-useful stimulation procedures and opens new doors for treatment of diseases that are related to autonomic dysregulation.
HRV Biofeedback
Protocols and hands-on practice

Paul Lehrer, PhD
Professor of Psychiatry
University of Medicine and Dentistry of New Jersey, Piscataway, NJ USA

This workshop will cover:
• 1. A protocol for determining resonance frequency
• 2. A protocol for doing biofeedback
• 3. Case material
• 4. Hands-on experience: finding your own resonance frequency
• 5. Open mike discussion: issues in procedures and applications of HRV biofeedback

SESSION 1 PROTOCOL

• Diagnosis
• Rationale
• Determine resonance frequency
• Check baseline rest for presence of LF peak
• Ask client to breathe slowly, and to maximize swing in HR peak to trough

• Validate resonance frequency using paced breathing
  – Use respiration pacer
  – Vary respiration rates around suspected Resonance frequency
• Train to breathe at Resonance frequency
  – With wrist watch
  – With respiration pacer

Determining resonance frequency

• Highest low-frequency spectral peak
• Highest internal coherence
  – Smooth HR wave at paced frequency
• Respiration and HR in phase
• Few or no “beats”
Baseline

6/min (not resonance frequency)

5.5/min (not resonance frequency)

5/min (not resonance frequency)

4.5/min **RESONANCE FREQUENCY**

4/min (not Resonance frequency)
**“INTERNAL COHERENCE”**

**Average Heart Rate (BPM)**

**Coherence Level Ratio**

---

**HR and Respiration at Resonance Frequency**

76 year-old male

---

**Slow breathing at Resonant Frequency – 6.0 bpm**

---

**Beats Occur when Driving Frequency is Close to the Natural Frequency of a System**

Example of Musical Tones

---

**Example of Resonance Characteristics: High total amplitude all at single frequency, “ringing”**

---

**SESSION 2**

- Breathe at Resonance frequency
- Relaxed abdominal breathing
- Exhale through pursed lips
- Breathe out longer than in
- Don’t try too hard
Session 3

- Same as session 3
- Turn off the pacing signal, and try to maximize HRV amplitude from cardiotachometer
- Determine actual respiration rate during this procedure

Subsequent Sessions

- Same as Session 3
- Generally: training is complete after 4 sessions
- Patient requires coaching in using the technique in daily life and in continued practice
- Integrate in psychotherapy
Clinical Applications

- Chernigovskaya et al: neurotic problems in general
  - Anxiety disorders
  - Depression
    - (Vagus nerve stimulation helps depression?)
  - Psychosomatic problems
    - Hypertension
    - Asthma

Studies of Asthma

- Pilot study of RSA biofeedback vs. EMG-assisted relaxed breathing
- 20 consecutive cases from Biosvyaz
- Initial results of controlled trial of 95 asthma patients

RSA Biofeedback Outcome: Biosvyaz Study of 20 Consecutive Unmedicated Asthmatic Children

<table>
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<th>Measure</th>
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<th>SD</th>
<th>Sdiff</th>
<th>t</th>
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<td>.72</td>
<td>.06</td>
<td>4.62</td>
<td>.0002</td>
</tr>
</tbody>
</table>

HRV biofeedback vs. relaxation and EMG biofeedback vs. waiting list

Forced Oscillation Pneumography

Pilot Study Strain Gauge
Low Frequency HR Variability (.03-.12 Hz)

MVV Pilot Study

Hyperventilation & RSA Biofeedback

Subjects: Controlled Trial of 95 asthmatic subjects
- 95 adult patients with asthma
  - Age 18-65
  - 66 female, 29 male
- Paid $100 for attending each of four sessions (the 1st, 4th, 7th, and 10th). No payment for medical visits or other training sessions

Controlled trial procedures
- Four groups
  - Full protocol: RSA bfk, pursed lips abdominal breathing, longer exhalation than inhalation
  - RSA biofeedback alone
  - Frontal EEG “biofeedback” + suggestion
  - Waiting list
  - 10 weekly biofeedback sessions

Controlled trial procedures
- Pulmonary function assessed in each session.
- Full physiological assessments at Sessions 1, 4, 7, and 10
- Daily Questionnaires
  - peak flow 4 times a day
  - asthma symptoms
  - medication consumption RSA biofeedback alone
Inclusion Criteria

Inclusion criteria
- History of symptoms consistent with asthma
- Positive bronchodilator test
  - Post-bronchodilator FEV₁ increase ≥ 12%
- OR positive methacholine challenge test

Exclusion Criteria

History of
- Abnormal cardiac rhythm
- A disorder that would impede performing the biofeedback procedures or require medication that would affect the autonomic nervous system
- A negative methacholine challenge test

Exclusion Criteria (cont’d)

- Abnormal diffusing capacity
  - Tested among all subjects > 55 years old or with more than 20 pack years of smoking
- Current practice of any relaxation, biofeedback, or breathing technique.

TREATMENT GROUPS

(restricted randomization procedure, balanced for age, sex, and asthma severity at the end of stabilization)

TREATMENT GROUPS (cont’d)

- Full protocol
  - HRV biofeedback + abdominal pursed-lips breathing with prolonged exhalation
- HRV biofeedback alone
- Placebo biofeedback
  - (EEG biofeedback + relaxing music + "subliminal suggestions")
- Waiting list control

Restricted Randomization

- Balanced for
  - Age
  - Sex
  - Asthma severity at the end of stabilization
DESIGN

adapted from a study of monteleukast effects on tapering inhaled steroids


---

TITRATE MEDICATION DURING TREATMENT

- Every 2 weeks
- Keep medication constant if any one criterion is present in the past two weeks.
- Increase medication by one step if two or more criteria are present in the past two weeks.
- Reduce medication by one step if no criteria are present in the past two weeks.

---

Criteria for Changing Medication (2-week time frame)

- FEV1 < 80% of baseline at any time
- PEF < 80% of personal best or PEF variability > 20% for 3 or more days
- Nocturnal asthma awakenings > 2
- One or more asthma flares not resolved by 6 p albuterol within one hour.
- Average of 8 p albuterol daily.

---

CRITERION FOR RESOLUTION OF ASTHMA FLARE

- No cough, wheeze, dyspnea, or chest tightness
- Peak flow >80% of personal best (defined as the highest level previously reported during the study)
- Can do usual activities.

---

Medication Protocol

<table>
<thead>
<tr>
<th>Type</th>
<th>Medication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Intermittent</td>
<td>No daily meds</td>
</tr>
<tr>
<td></td>
<td>Albuterol 4 p Alb/d</td>
</tr>
<tr>
<td>Mild Persistent</td>
<td>Fluticasone 44mcg/d</td>
</tr>
<tr>
<td></td>
<td>Flu 88 mcg/d</td>
</tr>
<tr>
<td></td>
<td>Flu 176mcg/d</td>
</tr>
<tr>
<td>Moderate Persistent</td>
<td>Flu 220mcg/d</td>
</tr>
<tr>
<td></td>
<td>Add Salmeterol or montelukast sodium</td>
</tr>
<tr>
<td></td>
<td>Flu 440 mcg/d</td>
</tr>
</tbody>
</table>
Medication Protocol (cont’d)

- Severe Persistent
  - 9 Flu 660 mcg/d
  - 10 Flu 880 mcg/d
  - 11 Add Salmeterol or montelukast sodium (continue the other of these drugs)
  - 12 Flu 1760 mcg/d
  - 13 Prednisone burst (40 mg to taper)

“treatment failure” = need to increase medication (pulmonologists are blinded; medication changes were based on pulmonary function and symptoms)

PULMONARY FUNCTION TESTS

Asthma Symptoms (From Daily Diaries)
Forced Oscillation Pneumography

- Impedance at low frequencies (6-10 Hz)
- Difference in impedance between low and high (20-32 Hz) frequencies
- First resonant frequency of the lung (a measure of tissue compliance)

Forced oscillation pneumography: Healthy subject

Forced oscillation pneumography: patient with severe asthma

Log Oscillation Resistance at 6 Hz

Respiratory Impedance at 6 Hz: Biofeedback - Rest Periods

Frequency-Dependent Resistance Drop

- Full Protocol
- HRV Biofeedback Alone
- Placebo Biofeedback
- Waiting List
Frequency-dependent Drop in Resistance
Biofeedback - Rest Periods

Lung Resonant Frequency
Biofeedback - Rest Periods

Low-Frequency Heart Rate Variability

High-Frequency Heart Rate Variability

Alpha Low-frequency Baroreflex Gain
Gevirtz’s Pilot Studies

- Five of six hypertensive subjects receiving biofeedback therapy became normotensive after treatment, while only four of 8 subjects in a no-biofeedback control group met this criterion.
- In study of 91 hypertensives, BP decreased 9.8/5.5 mm Hg

Age Effects and Response to HRV Biofeedback in Asthma

McCraty et al (2003) 1-session intervention n = 32
Gevirtz: Pediatric Abdominal Pain

Figure 1. Visual Analog scale from daily pain diary records, pre & post treatment, by group (Humphreys, Gevirtz, & Jacobs, 1999)

- Pre = Pre-treatment
- Post = Post-treatment

4 component = fiber + biofeedback + cognitive restructuring + parental support
3 component = fiber + biofeedback + cognitive restructuring
2 component = fiber + biofeedback

Gevirtz: Does Biofeedback Increase HRV in CAD?

- 61 participants: Tx=30, Cont=31
- Coronary artery disease: >50% blockage of LAD, RC, or circumflex artery; reversible perfusion defect; inducible wall motion abnormality; coronary intervention.
- 7 sessions: 6 treatment, 3-month follow-up
- 4 groups

SDNN (ms) Results

Week 1  Week 7  Week 18

(Treatment)  (Control)

(Week 1)  (Week 7)  (Week 18)

(Gevirtz, 2004)

4 Groups

- Healing Hearts: Comprehensive cardiac rehab program at Scripps Center for Integrative Medicine
  - Treatment
  - Control
- Non Healing Hearts
  - Treatment
  - Control

Combined Heart Rate Variability and Pulse Oximetry Biofeedback for COPD: Preliminary Findings

Nicholas D. Giardino, Ph.D.
Department of Psychology
University of Cincinnati
Feasibility Study: Combined HRV and Pulse Oximetry Biofeedback for COPD

**Participants:**
20 people with COPD who had already participated in a pulmonary rehabilitation program within the past year
- age 48-79 [mean(SD) = 63(9.6)]
- FEV₁ mean(SD) = 46(16)% of predicted

**Outcome Measures:**
- **Primary**
  - 6-MWD
  - Quality of Life (SGRQ)
- **Secondary**
  - Anxiety and Depression (HADS)
  - COPD Self-Efficacy
  - Functional status (PFSDQ-M)
  - Dyspnea

---

**Results**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pre-Treatment Mean (SD)</th>
<th>Range</th>
<th>Post-Treatment Mean (SD)</th>
<th>Range</th>
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<tbody>
<tr>
<td>6-MWD (meters)</td>
<td>249 (97)</td>
<td>19 – 424</td>
<td>432 (153)**</td>
<td>42 – 620</td>
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<tr>
<td>Quality of Life (SGRQ)</td>
<td>50.1 (18.5)</td>
<td>20 – 86.3</td>
<td>46.0 (24.2)**</td>
<td>21.4 – 70.9</td>
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<tr>
<td>Anxiety (HADS)</td>
<td>8.4 (4.0)</td>
<td>2 – 19</td>
<td>7.7 (3.7)</td>
<td>2 – 17</td>
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<tr>
<td>Depression (HADS)</td>
<td>8.1 (4.3)</td>
<td>4 – 19</td>
<td>7.3 (4.1)</td>
<td>3 – 16</td>
</tr>
<tr>
<td>COPD Self-Efficacy</td>
<td>69 (22)</td>
<td>18 – 88</td>
<td>62 (29)*</td>
<td>25 – 88</td>
</tr>
<tr>
<td>Activity Impairment (MPHQD)</td>
<td>4.6 (1.6)</td>
<td>2.5 – 8.0</td>
<td>3.3 (1.8)*</td>
<td>3.0 – 7.3</td>
</tr>
</tbody>
</table>

* p < .01
* clinically significant change

---

**Fibromyalgia Study (n=11)**

**Inclusion criteria:**
- Women age 18-65
- Meets criteria of Am Coll Rheumatol
- Dx of Fibromyalgia by board-certified rheumatologist
- Speaks English

**Exclusion criteria:**
- Other serious medical or psychological illness that poses risk
- Cognitive impairment that would limit ability to provide consent

---

**Fibromyalgia Questionnaire Data n=11**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Session 1</th>
<th>Session 10</th>
<th>3-month Follow-up</th>
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<tbody>
<tr>
<td>FIQ</td>
<td>p &lt; .02</td>
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<tr>
<td>MPQ</td>
<td>p = n.s.</td>
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<tr>
<td>BDQ</td>
<td>p = n.s.</td>
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<tr>
<td>PSQI</td>
<td>p &lt; .05</td>
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</table>

---

**Feasibility Study: Combined HRV and Pulse Oximetry Biofeedback for COPD**
Controlled Study of Psychophysiological Therapy for Multiple Unexplained Symptoms

- Interim results: 15 subjects/group, 12 in crossover.
- Ten session treatment
  - Treatment (flexible, as appropriate)
    - doctors letter
    - Progressive relaxation, autogenic training
    - Biofeedback
      - sEMG, finger temperature, HRV, ETCO2
  - Control --- doctors letter only
  - Crossover: Treatment condition after control
CASE MATERIAL

PATIENT DATA
- 44 year-old female nurse
- History of gradual adult-onset asthma
- Allergic to many things. Does not leave home for vacations because of severe asthma attacks
- Frequent severe asthma exacerbations requiring hospitalization and administration of oral steroid medication

FIRST WEEK

DAILY WORST SYMPTOMS
- 1. Mild to moderate, mildly irritating
- 2. Moderate to severe, extremely irritating
- 3. Moderate to severe, distressing
- 4. Moderate to severe, mildly distressing
- 5. Moderate, mildly irritating
- 6. Mild, not unpleasant
- 7. Mild to moderate, mildly irritating

DOSES OF DRUG
- 1. Flovent (4), Singulair (1)
- 2. Flovent (4), Singulair (1)
- 3. Flovent(4), Singulair(1), Proventil (4)
- 4. Flovent(4), Singulair(1), Proventil (4)
- 5. Flovent(4), Singulair(1), Proventil (4)
- 6. Flovent(4), Singulair(1), Proventil (4)
- 7. Flovent(4), Singulair(1), Proventil (3)

Comments Week 1
- 1. Chest feels tight. I feel like enough air gets in/out, but feels like less exchange is taking place. I feel hypoxic. Also coughing started today.
- 2. Asthma was a problem today. Tight chest. Peak flow higher than usual (425) but I still feel like I am not getting enough oxygen. Biofeedback session was hard and tiring. I can't breathe through my nose. My nasal passages are swollen. I could not relax.
- 3. Asthma was worse than yesterday. Walking made my short of breath. I feel hypoxic. Flovent giving me a sore throat. Takes a lot to just to focus on relaxation.
- 4. Too tense to focus on relaxation. Couldn't do much but lie around. Feel stressed because it taking days to feel better. Proventil gives me the shakes.
- 6. Finally feeling asthma is under control. Just feel it returning when I go outside (hot humid temperature).
- 7. Feeling much better. Relaxation technique is more relaxing to do.

Fifth week

DAILY WORST SYMPTOMS
- 1. Not noticeable, not unpleasant
- 2. Not noticeable, not unpleasant
- 3. Mild to moderate, mildly irritating
- 4. Moderate, irritating
- 5. Mild to moderate, mildly irritating
- 6. Mild to moderate, mildly irritating
- 7. Mild, not unpleasant

DRUGS
- 1. None
- 2. None
- 3. None
- 4. None
- 5. None
- 6. None
- 7. Singulair(1)

Comments Week 5
- 1. Trying to use biofeedback walking. This is hard! I get out of breath right away.
- 2. None
- 3. Walking and trying to use biofeedback is hard. I can only do a 1:3 pattern at best. When I do biofeedback while sitting, I use a watch to make sure that I am counting correctly. Sometimes the second hand seems to stop moving.
- 4. Rather stressful day—Still trying to use biofeedback while walking. Very difficult to lengthen my breathing pattern. But I am getting a 20-beat difference in heart beat during biofeedback while sitting.
- 5. Still trying to use the technique while walking/stair climbing. Best I can manage is 2 "in", 4 "out".
- 6. (5 days later, reports: "Exercise is getting easier")
Eighth Week

- **DAILY WORST SYMPTOMS**
  - 1. Mild to moderate, mildly irritating
  - 2. Not noticeable, not unpleasant
  - 3. Not noticeable, not unpleasant
  - 4. Not noticeable, not unpleasant
  - 5. Not noticeable, not unpleasant
  - 6. Mild, not unpleasant
  - 7. Not noticeable, not unpleasant

- **DRUGS**
  - 1. None
  - 2. None
  - 3. None
  - 4. None
  - 5. None
  - 6. None
  - 7. None

Comments Eight Week

- 1. Stress level is increasing, exercise is increasing. No problems with asthma!
- 2. When I feel my chest getting tight I just close my eyes and do the breathing, and imagine the beeps of the machine.
- 3. Symptoms are only activity-induced, and last a very short time.

THREE CASE STUDIES OF
ASTHMA

Clinically significant treatment results included decreases asthma symptom severity, decreases in medication consumption and increases in pulmonary function. In all three cases, treatment results began to appear after first session. Peak flow gradually increased and asthma symptom severity decreased during the first month from first to the fourth session. After the fourth session, treatment results stabilized and the physician began to decrease medications. In two cases, after three months of treatment, the patients no longer took any asthma medication, and remained symptom-free with improved pulmonary function. Positive results were maintained during the follow up month.

Clinical Condition (Patient 042)

After session 1- (8/31/2000). Dx- Moderate Persistent Asthma; Flovent 44 2p BID and Serevent 50 1p BID, FEV1 (pre-session)- 95% FEV1 (post-session)- 98%, Average morning Peak Flow=465 L/min.

After session 4- (9/28/2000). Dx- Moderate Persistent Asthma; Flovent 44 2p BID, FEV1 (pre-session)- 96%, FEV1 (post-session)- 96%, Average morning Peak Flow=490 L/min.

After session 7- (10/26/2000). Dx- Mild Persistent Asthma; Flovent 44 2p BID, FEV1 (pre-session)- 99%, FEV1 (post-session)- 99%, Average morning Peak Flow=510 L/min.

After session 10- (11/16/2000), Dx-Mild Persistent Asthma; Flovent 44 1p BID, FEV1 (pre-session)- 92%, FEV1 (post-session)- 94%, Average morning Peak Flow=500 L/min.

After BFB treatment - (11/16/2000)/ 1st visit to asthma physician,
Dx- Mild Persistent Asthma, Flovent 44 1p BID, Average morning Peak Flow= 500 L/min.

After BFB treatment - (11/30/2000)/ 2nd visit to asthma physician. Dx- Mild Persistent Asthma, Flovent 44 1p QD. Average morning Peak Flow= 490 L/min.
### Patient 042 Asthma Severity

<table>
<thead>
<tr>
<th>Session</th>
<th>Symptoms</th>
<th>Pulmonary Function</th>
<th>Medication</th>
<th>Overall</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Moderate</td>
<td>Mild Intermittent</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Moderate</td>
<td>Mild Persistent</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>7</td>
<td>Mild Intermittent</td>
<td>Mild Intermittent</td>
<td>Mild Persistent</td>
<td>Mild Persistent</td>
</tr>
<tr>
<td>10</td>
<td>Mild Intermittent</td>
<td>Mild Intermittent</td>
<td>Mild Persistent</td>
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<tr>
<td>Follow-up</td>
<td>Mild Intermittent</td>
<td>Mild Intermittent</td>
<td>Mild Persistent</td>
<td>Mild Persistent</td>
</tr>
</tbody>
</table>

### Clinical Condition (Patient 007)

**After session 1** - (7/19/2000). Dx- Moderate Persistent Asthma; Flovent 110 2p BID, FEV1 (pre-session)- 63%, FEV1 (post-session)- 62%, Average Average morning Peak Flow- 290 L/min.

**After session 4** - (8/8/2000). Dx- Moderate Persistent Asthma; Flovent 110 1p BID, FEV1 (pre-session)- 65%, FEV1 (post-session)- 65%, Average morning Peak Flow- 280 L/min.

**After session 7** - (9/12/2000). Dx- Mild Persistent Asthma; Flovent 44 2p BID, FEV1 (pre-session)- 67%, FEV1 (post-session)- 64%, Average morning Peak Flow- 340 L/min.

**After BFB treatment** - 1st visit to asthma physician. Dx- Mild Persistent Asthma, no medications, Average Average morning Peak Flow- 330 L/min.

**After BFB treatment** - (10/02/2000). Dx- Mild Persistent Asthma; Flovent 44 1p BID, FEV1 (pre-session)- 67%, FEV1 (post-session)- 67%, Average morning Peak Flow- 320 L/min.

**After BFB treatment** - (10/5/2000) 2nd visit to asthma physician. Dx- Mild Persistent Asthma, no medications, Average morning Peak Flow- 320 L/min.

### Patient 007 Asthma Severity

<table>
<thead>
<tr>
<th>Session</th>
<th>Symptoms</th>
<th>Pulmonary Function</th>
<th>Medication</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Moderate</td>
<td>Severe</td>
<td>Moderate</td>
<td>Severe</td>
</tr>
<tr>
<td>4</td>
<td>Mild Persistent</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>7</td>
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<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>10</td>
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<td>Moderate</td>
<td>Mild Persistent</td>
<td>Moderate</td>
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<td>Follow-up</td>
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<td>Mild Intermittent</td>
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</table>
Low Frequency Baroreflex Gain
Patient 007

Clinical Condition (Patient 034)

After session 1 – (10/13/1999). Dx - Moderate Asthma; Azmacort - 3p. BID, FEV1 (pre-session) - 73%, FEV1(post-session) - 77%, Average morning Peak Flow – 340 L/min.

After session 4 – (11/04/1999). Dx - Moderate Asthma; Azmacort - 3p. BID, FEV1(pre-session) - 85%, FEV1(post-session) - 79%, Average morning Peak Flow – 390 L/min.

After session 7 – (11/24/1999). Dx - Mild Persistent Asthma; Azmacort - 2p. BID, FEV1 (pre-session) - 79%, FEV1(post-session) - 78%, Average morning Peak Flow – 390 L/min.

After session 10 – (12/16/1999). Dx - Mild Persistent Asthma; Azmacort - 1p. BID, FEV1 (pre-session) - 80%, FEV1 (post-session) - 75%, Average morning Peak Flow – 400 L/min.

After BFB treatment – (01/06/2000) 1st visit to asthma physician. Dx - Mild Persistent, no medications, Average morning Peak Flow – 400 L/min.

After BFB treatment – (01/21/2000) 2nd visit to asthma physician. Dx - Mild Intermittent, no medications, Average morning Peak Flow – 400 L/min.

Clinical Condition (Patient 034)

After session 1 – (10/13/1999). Dx - Moderate Asthma; Azmacort - 3p. BID, FEV1 (pre-session) - 73%, FEV1(post-session) - 77%, Average morning Peak Flow – 340 L/min.

After session 4 – (11/04/1999). Dx - Moderate Asthma; Azmacort - 3p. BID, FEV1(pre-session) - 85%, FEV1(post-session) - 79%, Average morning Peak Flow – 390 L/min.

After session 7 – (11/24/1999). Dx - Mild Persistent Asthma; Azmacort - 2p. BID, FEV1 (pre-session) - 79%, FEV1(post-session) - 78%, Average morning Peak Flow – 390 L/min.

After BFB treatment – (01/06/2000) 1st visit to asthma physician. Dx - Mild Persistent, no medications, Average morning Peak Flow – 400 L/min.

After BFB treatment – (01/21/2000) 2nd visit to asthma physician. Dx - Mild Intermittent, no medications, Average morning Peak Flow – 400 L/min.

Asthma Severity Patient 034

<table>
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<th>Session</th>
<th>Symptom</th>
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<th>Medication</th>
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<td>Mild Intermittent</td>
<td>Mild Intermittent</td>
<td>Severe</td>
</tr>
</tbody>
</table>
Low Frequency Spectral Baroreflex Gain Subject 034

Fig 3. Hypertensive patient's evening BP

Panic Disorder Patient

Resonance Frequency Breathing and Hyperventilation

64 year old woman with anxiety, depression, and chronic cough