Heart Rate Variability and Heart Rate Variability Biofeedback

Paul Lehrer, PhD

AGENDA

• How HRV reflects autonomic balance, autonomic activity, and adaptability
• HF, LF, and VLF HRV
  – Autonomic correlates
  – Reflex correlates
• Effects of HRV biofeedback on HRV, the baroreflex, and the inflammatory response
• Time necessary to train HRV biofeedback
• HRV in Zen monks during tanden breathing

The Problems of the 1960’s and 70’s Psychophysiologist

Does HR go up or down with stress?
It is always changing. From where do you measure?
Oscillation as noise
Note three overlapping frequencies. Each frequency reflects a homeostatic reflex:
- High frequency
- Low frequency
- Very low frequency
Computer-Generated simulation of HRV: HF, LF, VLF models normal human HRV

- High Frequency (0.15 - 0.4 Hz): RSA, vagally mediated cardiac control, "cardiac vagal tone," "vagal modulatory activity" (Porges)
- Low Frequency (0.04 – 0.15 Hz): Both sympathetic and parasympathetic regulation, baroreflex control
- Very Low Frequency (0.003 – 0.04 Hz): Sympathetic mediation, thermal regulation (?)
- Ultra Low Frequency (< 0.003 Hz) Alertness (?)

Alternative Ranges
- ULF: < 0.005 Hz
- VLF: 0.005 - 0.05 Hz (blood pressure control through vascular changes, vascular baroreflex, thermal regulation, alpha sympathetic control)
- LF: 0.05 - 0.15 Hz (blood pressure control through heart rate changes, HR baroreflex, mostly parasympathetic but perhaps also beta sympathetic effects)
- HF: 0.15 - 0.4 Hz (respiratory sinus arrhythmia, parasympathetic control, affects gas exchange)

HRV and autonomic balance

• HF: vagal (parasympathetic)
• LF: sympathetic and vagal (some research suggests it is primarily vagal)
• VLF: (alpha) sympathetic
• LF/HF ratio: sometimes interpreted as sympathetic:parasympathetic balance
• Normalized LF and HF are interpreted similarly to LF/HF
  ≈ LF / (LF + HF)
  ≈ HF / (LF + HF)

HRV represents healthy cardiovascular and autonomic modulation

When a function goes up a reflex makes it go down

When a function goes down a reflex makes it go up
Some Sources of HRV

- Respiratory sinus arrhythmia (RSA)
  - HF HRV, under control of the vagus (parasympathetic) nerve
- Baroreflex
  - Heart rate
  - Vascular tone
- Thermal regulation
- Various regulatory processes

Contributors to Heart Rate Variability
RSA and the baroreflexes

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
HRV BIOFEEDBACK

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Example of High Level of Respiratory Sinus Arrhythmia

Notice how heart rate increases with inhalation. Heart rate decreases with exhalation. This pattern shows a high amount of RSA and is typical of that achieved during HRV biofeedback.
HRV BIOFEEDBACK EFFECTS

- Primarily affects the parasympathetic nervous system
- Strengthens regulation; targets dysregulation
  - Targets autonomic balance
  - Strengthens the baroreflex (a homeostatic reflex)
  - HRV biofeedback targets respiratory regulation / interaction with respiration
    - It increases oscillations
    - It produces phase relationships that interact among heart rate, blood pressure, and breathing
    - It affects other processes:
      - Blood pressure regulation
      - Respiratory regulation
      - Emotional regulation
64 year old woman with anxiety, depression, and chronic cough

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“Artificial RSA” Study

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BUT 0° phase relationship between heart rate and breathing in intact humans occurs only during resonance-frequency breathing
HR Association with Breathing

At ~0.1 Hz (6/min) HRV amplitude is highest and respiration has 0° phase with HR

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

Baroreflex gain
• BPM change in heart rate / mm Hg change in BP measured various ways as previously described
Correlates of HRV amplitude

- Youth
- Aerobic fitness
- Being a pre-menopausal woman
- Survival in ICU and severe heart failure

- Health: absence of
  - Infection
  - Inflammation
  - Diabetes
  - Heart disease
  - Hypertension
  - Mental illness
  - Stress
  - Etc.

Changes with Age in RRI Variability Spectral Power in the Low Frequency Range (0.05-0.15 Hz)

Changes with Age in Total RRI Variability Spectral Power
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


Resonance Frequency Breathing and Hyperventilation
Inflammatory System Effects?

- Cholinergic neurons inhibit acute inflammation

Inflammatory Effects

- Vagus nerve stimulation attenuates the systemic inflammatory response to endotoxin

The effects of heart rate variability (HRV) biofeedback for in vivo endotoxin induced systemic inflammation

- Ou Oikawa
- Maria Katsamanis Karavidas
- Shou-En Lu
- Susette M. Coyle
- Marie Macor
- Steve E. Calvano
- Stephen F. Lowry
- Paul M. Lehrer
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

MODULATION OF THE FOLLOWING LPS EFFECTS

- Increased respiration rate
- Decreased HRV at all frequencies
- Symptoms of severe infection
Log SDNN

![Graph showing Log SDNN with two groups, Control and HRV Biofeedback.](chart1)

Task 0, 1, 2, 3, 4, 6, 8, 24

Training Session

Log LF HRV

![Graph showing Log LF HRV with two groups, Control and HRV Biofeedback.](chart2)

Task 0, 1, 2, 3, 4, 6, 8, 24

Log HF HRV

![Graph showing Log HF HRV with two groups, Control and HRV Biofeedback.](chart3)

Task 0, 1, 2, 3, 4, 6, 8, 24

Log ms

Task 0, 1, 2, 3, 4, 6, 8, 24
Symptom Effects

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)

It takes about 4 hours of training to teach the skill

First & Fourth Sessions

Frequency Analysis of HRV Across RSA Biofeedback Training Sessions
70 Year Old Zen monk at rest

70 year old Zen monk during tanden breathing

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SUMMARY

- HRV reflects autonomic balance, autonomic activity, and adaptability
  - They are not the same
- HF, LF, and VLF HRV
  - Autonomic correlates
  - Reflex correlates
- Effects of HRV biofeedback on HRV, the baroreflex, and the inflammatory response
- Time necessary to train HRV biofeedback
- Zen monks achieve HRV similar to that in HRV biofeedback