

Moss, D. (2004). Heart rate variability and biofeedback. *Psychophysiology Today: The Magazine for Mind-Body Medicine*, 1, 4-11.

Original Article

Heart Rate Variability (HRV) Biofeedback

Donald Moss, Ph.D. (2004)

Abstract: Heart rate variability (HRV) is a critical marker of a healthy organism. Low HRV predicts greater morbidity and mortality after heart attack, and also predicts death by all causes. HRV biofeedback can increase the adaptive and coherent variability in heart rate, and moderate the symptoms of asthma, COPD, and other autonomically mediated medical conditions. Diaphragmatic breathing, cognitive relaxation, and positive emotion are conducive to optimal increases in HRV.

Key Words: biofeedback, heart rate variability, asthma, anxiety, COPD, cardiovascular rehabilitation

Heart Rhythms and Human Health:

The human heart is a four-chambered bioelectric pump beating at an ever changing rate. This variability in heart rate is an adaptive quality in a healthy body. By variability we mean changes in the interval or distance between one beat of the heart and the next, as measured in milliseconds (DeIpozo, et al., 2004). The *interbeat interval* (IBI) is the time between one R wave (or heart beat) and the next, in milliseconds. The IBI is highly variable within any given time period. Multiple biological rhythms overlay one another to produce the resultant pattern of variability. Interbeat interval variations, or heart rate variability, have relevance for physical, emotional, and mental function.

As human beings age or suffer illness, the total variability in heart rate is reduced, and the risk of illness and death increases. Regular exercise increases heart rate variability. Scientific study of the variability in heart rate is fairly recent, and only in the past ten years did it become possible to train human beings to change the variability in heart rhythms, through biofeedback training.

Several clinical findings show the importance of the heart's variability: Changes in the rhythms of the heart occur before a fetus goes into distress, and decreased variability may predict sudden infant death. Lower variability in heart rate predicts a greater risk for further cardiac symptoms and death after a heart attack (Kleiger, et al., 1987). Clinical depression also lowers heart rate variability, and increases risk for coronary artery disease (Carney, et al., 2001). Heart rate variability has come to be regarded as a useful prognostic index or marker for morbidity and mortality.

Autonomic Balance

The rate at which the heart beats is governed by two internal "pacemakers" -- the sinoatrial (SA) and atrioventricular (AV) nodes, which are responsible for heart rhythms. The SA node initiates an electrical signal which begins each cycle of the heart's pumping action. This signal passes through the AV node which spreads the electrical current through the ventricles of the heart.

The body's autonomic nervous system (ANS) governs many of the body's internal functions, through the two pacemakers. The sympathetic branch of this ANS activates or increases the heart's action, while the parasympathetic branch acts as a brake slowing the action of the heart. The vagus nerve plays a role in the

parasympathetic braking action. The balance between this throttle and brake system produces an ongoing oscillation, an orderly increase and decrease in heart rate. Training in HRV biofeedback does not appear to simply increase parasympathetic or sympathetic dominance; rather it exercises the balance between the two.

A variety of factors, including breathing, pressure sensors (Baroreceptors) in the arteries, the body's thermal regulation, and anxious thinking, increase specific rhythms in heart activity. The overall process of heart function is the end product of these various sub-rhythms.

Research on Heart Rate Variability

Research on HRV traces back in the United States to the research in the 1960's and 1970's by John and Beatrice Lacey (Lacey, 1967; Lacey & Lacey, 1964, 1978), suggesting that changes in cardiovascular function facilitated or inhibited cortical processing. Their classic 1978 article suggested a "two way communication between the heart and the brain." They showed, for example, that the greater the cardiac deceleration, the faster the individual's reaction time. Cardiac deceleration coincides with a phase of attention and preparation for action. This perspective was applied by Carlstedt to athletic performance (2001).

A second thread of applied research on HRV leads back to Russian researchers, who trained subjects to increase heart rate variability by a combination of biofeedback and breath training, producing decreases in asthma symptoms and other autonomically mediated disorders (Lehrer, Vaschillo, & Vaschillo, in press). It was largely this second thread of Russian research which spurred the current interest in clinical applications of HRV biofeedback to medical and psychological disorders.

Heart Rate Variability Biofeedback

Heart Rate Variability Biofeedback, or HRV biofeedback, is a relatively new technique training human beings to change the variability and dominant rhythms in their heart activity. Research is now going on in several sites, applying HRV biofeedback to medical and psychiatric conditions including: anger, anxiety disorders, asthma, cardiovascular conditions, irritable bowel syndrome, chronic fatigue, chronic pain, fibromyalgia, etc.

Initial case reports and small research studies are raising hopes that HRV biofeedback can help patients with these conditions (Bhat & Bhat, 1999; Gevirtz, 2000, 2003; Herbs, Gevirtz, & Jacobs, 1994; Del Pozo & Gevirtz, 2003).

Some more rigorous recent studies are strengthening these hopes for HRV biofeedback. For example, Lehrer and colleagues recently published an article in *Chest*, describing substantial moderation of asthma symptoms, using a protocol including HRV biofeedback, with or without training in pursed lipped diaphragmatic breathing (Lehrer, et al., 2004). Similarly, Giardino, Chan, and Borson (2003) combined HRV biofeedback with exercise guided by pulse oximetry feedback for patients with chronic obstructive pulmonary disease, and reported a significant improvement in the distance walked in six minutes, and in quality of life as measured by a respiratory questionnaire. Significant improvements were also seen in self-efficacy, disability, and dyspnea. Finally, Del Pozo, et al. (2004) provided HRV biofeedback to patients with coronary artery disease, and demonstrated a significant increase in the patient's heart rate variability (as measured by the SDNN index). This result suggests that HRV biofeedback is a promising tool for improving survival rates in coronary artery disease.

Training Criteria for HRV Biofeedback

Research and clinicians reports frequently refer to “providing HRV biofeedback training” to a group of subjects, without specifying further what specific responses the biofeedback is monitoring or reinforcing. Others report “doing RSA training,” which can mean anything from training the subject to create parallel sinusoidal line graphs for respiration and heart rate, to training the patient to increase the amplitude in the sinusoidal line graph. In the following we will describe several complementary training strategies, each of which can effectively be used to increase cardiac variability in a health enhancing fashion. Today’s computer interfaced biofeedback systems can be programmed to guide the subject in each of the training strategies described here.ⁱ

Increasing Heart Rate Variability

One measure of heart rate variability is the difference between the highest heart rate and the lowest heart rate within each cardiac cycle. Twenty year olds often show a swing of five to ten points between the high and low points in their heart rates. Persons over fifty often show changes of only three to five beats. Persons who are more physically active show a wider range between their maximal and minimal heart rate. HRV biofeedback can enable the individual to increase this variability in heart rate, sometimes producing a range of fifty beats a minute during training. HRV biofeedback training can focus on increasing the HR Max –HR Min index. (Objective 1 = increasing HR Max – HR Min).

SDNN

Another Index of Heart Rate Variability, widely used in medical research is the Standard Deviation of the N to N interval. The N to N interval is the “normalized” beat to beat interval. The SDNN is the standard deviation of those intervals, a measure of how variable those intervals are. The SDNN is a measure in milliseconds (ms). The trainee in HRV biofeedback can also be directly reinforced for including the SDNN index. (Objective 2 = increasing SDNN).

Directing Heart Rhythms

A statistical technique called “spectral analysis” allows us to see the component rhythms that make up the overall rhythm of heart activity. HRV biofeedback uses this spectral analysis to train increases in specific rhythms.

Heart rate changes are driven by several biological governors, each producing changes in specific time frames. Statistically, these can be separated out as waveforms of varying frequencies. The Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996) established a standard for categorizing these frequency ranges:

High Frequency -- .15 - .4 Hz

Low Frequency -- .04 - .15 Hz

Very Low Frequency -- .0033 - .04 Hz

Ultra Low Frequency -- < .0033, beyond biofeedback measurement technology

Psychophysiological research suggests that these frequency ranges reflect the following biological influences:

- High Frequency – parasympathetic pathways, the influences of respiration in normal frequencies on vagal tone
- Low Frequency – influence of BP rhythms (baroreceptors) on heart rhythms (meditative/slow breathing augments this range)
- Very Low Frequency – sympathetic activation, or more probably the withdrawal of parasympathetic braking, also the influences of visceral and thermal regulation. Rumination and worry augment this range.
- Ultra Low Frequency—slower acting biological influences

Biofeedback training can focus on increasing the amount of total HRV in a specific frequency range. To date, it appears optimal to increase the amount of heart rate change in the Low Frequency Range. Evgeny Vaschillo, the Russian physiologist, hypothesizes that there is a “resonant frequency,” native to each organism, which is optimal for overall health. For most persons that resonant frequency involves a dominance of heart rate change in the Low Frequency (LF) range, around 0.1 Hz. HRV biofeedback can therefore guide and reinforce trainees for shifting their overall heart rate variability into the LF range. (Objective 3 = increasing percentage of overall heart rate change falling in the LF range).

This 0.1 Hz frequency is most frequently produced by persons in a relaxed mental state, with a positive emotional tone, breathing diaphragmatically at a rate of about 5-7 breaths per minute. Relaxed breathing at six breaths per minute produces a spike of heart rate variability at 0.1 Hz. Remember that one tenth of a Hertz equals one tenth of a cycle per second, so that 0.1 Hz equates mathematically to six cycles per minute. The other measures of HRV also tend to maximize when heart rate change is dominated by rhythms in this Low Frequency range. The amplitude of variation is higher, because the effects of the baroreceptors on heart rate are added to the effects of slow breathing on heart rate. So finally, HRV biofeedback can reinforce breathing in the 5-7 breaths per minute range, and reinforce the production of a dominant spike in HRV at 0.1 Hz. (Objective 4 = breathing at 6 breaths a minute and producing a dominant spike of HRV at 0.1 Hz.)

Tools in Modifying Heart rate Variability

Diaphragmatic Breathing: A number of strategies are helpful when an individual wants to control heart rate variability. First, diaphragmatic breathing is a critical tool for increasing heart rate variability and creating a coherent heart rhythm. In diaphragmatic breathing, the individual breathes deeply, smoothly, and fully, using the diaphragm muscles below the lungs. With each breath, the individual fills the lungs fully but without effort, and then empties the lungs fully and smoothly. Breathing continues evenly and smoothly at a rate of about six breaths per minute.

The calming effects of slow, full breathing have long been recognized in schools of meditation and yoga. Traditional Chinese medicine long ago observed the reciprocal relationship between regular breathing and the subject’s mental state: “... the tranquility of the mind regulates the breathing naturally and, in turn, regulated breathing brings on concentration of the mind naturally.” (*Questions and Answers of Meisha*, Yue Yanggui, Qing Dynasty, cited by Xiangcai, 2000, p. 7). The same source noted that: “...the mind and breathing are interdependent and regular respiration produces a serene mind.” (Yue Yanggui, cited by Xiangcai, 2000, p. 7).

Relaxation and Meditation: It is helpful to relax both physically and mentally, letting go of anxious thoughts, disturbing emotions, and muscular tensions. A variety of relaxation techniques are helpful,

including progressive muscle relaxation, Autogenic Training, and visualization techniques (Lehrer & Carrington, 2003). Meditation techniques are also helpful, enabling the individual to quiet and focus the mind (Baer, 2003; Carrington, 1993), since worrisome thoughts produce more sympathetic nervous activation, and disrupt the efforts to achieve one's Resonant Frequency.

Cultivating Positive Emotion: It is also helpful to cultivate positive, "feel-good" emotions, such as warmth, caring, and love, which appear to help the person enter a resonant frequency (Bhat & Bhat, 1999). For example, imagining someone like Mother Theresa caring for a sick child creates a warm feeling for most persons, which increases the orderliness or "coherence" of heart rhythms. In contrast, negative emotions such as anger and bitterness decrease the coherence of heart rate, and block the resonant frequency. A line graph tracking heart rate shows a ragged and irregular pattern during moments of anger; during positive emotion one sees a smooth sinusoidal variation with increasing amplitude in variation. A spectral analysis of heart rate shows a significant difference in heart rhythms during negative versus positive emotions, with much of the overall activity focused in the low range of Heart Rate Variability. Spectral displays during positive emotional states show a unimodal peak in heart rate variation, at about 0.1 Hz, corresponding to a relaxed, full and slow process of breathing at about 6 breaths per minute.

Both research and clinical practice show the harmful impact of negative emotions on cardiac health. Ironson, et al. (1992) reports that remembering anger decreases the ejection fraction of the heart, and Boltwood, et al. (1993) shows that remembering anger produces a spasm in arteries clogged with atherosclerosis. The Heart Math Institute in California has promoted training in positive emotions as a basic tool for health and wellness, and as a stepping stone toward optimal control of heart rate variability (Childre & McCraty, 2001; McCraty, Atkinson, & Tiller, 1995). In the same direction MacLean (2004) argues that that retraining heart rhythms can transform the person in emotions, relationships, and mode of awareness – toward "open-hearted" living and loving. In this sense HRV biofeedback presents a tool for personal transformation and not just for addressing medical disorders.

Summary

Diaphragmatic breathing, relaxation, meditation, the cultivation of positive emotion, and heart rate variability (HRV) biofeedback are interrelated techniques which can be helpful in improving heart health as well as overall well-being. Both the early research by the Lacey's and more recent work at the Heart Math Institute shows that HRV changes are integrally connected with transformations in thought and emotion. Recent research suggests a positive role for HRV biofeedback in the treatment of anxiety, asthma, chronic obstructive pulmonary disease, irritable bowel, and other autonomically mediated conditions. Several training strategies can be effective in training subjects to increase heart rate variability, and today's computer interfaced biofeedback systems can be programmed to reward each of the training criteria.

References

- Baer, R. A. (2003). Mindfulness as a clinical intervention: A conceptual and empirical review. *Clinical Psychology: Science and Practice*, 10, 125-143.
- Bhat, N., & Bhat, K. (1999). Anger control using biofeedback: A clinical model for heart patients. *Biofeedback*, 29 (4), 15-17.
- Boltwood, M. D., Taylor, C. B., Burke, M. B., Grogin, H., & Giacomini, J. (1993). Anger report predicts coronary artery vasomotor response to mental stress in atherosclerotic segments. *American Journal of Cardiology*, 72 (18), 1361-165.

- Carlstedt, R. (2001). Ambulatory psychophysiology and ecological validity in studies of sports performance: Issues and implications for intervention protocols in biofeedback. *Biofeedback*, 29 (4), 19-23.
- Carney, R. M., Blumenthal, J. A., Stein, P. K., Watkins, L., Catellier, D., Berkman, L. F., Czajkowski, S. M., O'Connor, C., Stone, P. H., & Freedland, K. E. (2001). Depression, heart rate variability, and acute myocardial infarction. *Circulation*, 104 (17), 2024-8.
- Carrington, P. (1993). The clinical use of meditation. In P.M. Lehrer and R.L. Woolfolk (Eds.), *Principles and practice of stress management*, 2nd edition (pp. 139-168). New York: Guilford Press.
- Childre, D., & McCraty, R. (2001). Psychophysiological correlates of spiritual experience. *Biofeedback*, 29 (4), 13-17.
- Del Pozo, J., & Gevirtz, R. N. (2003). Complementary and alternative care for heart disease. *Biofeedback*, 31(3), 16-17.
- Del Pozo, J. M., Gevirtz, R.N., Scher, B., & Guarneria, E. (2004). Biofeedback treatment increases heart rate variability in patients with known coronary artery disease. *American Heart Journal*, 147 (3), G1-G6.
- Gevirtz, R. N. (2003). The promise of HRV biofeedback: Some preliminary results and speculations. *Biofeedback*, 31(3), 18-19.
- Gevirtz, R. N. (2000). Resonant frequency training to restore homeostasis for treatment of psychophysiological disorders. *Biofeedback*, 27, 7-9.
- Giardino, N. D., Chan, L., & Borson, S. (2004). Combined heart rate variability and pulse oximetry biofeedback for chronic obstructive pulmonary disease. *Applied Psychophysiology and Biofeedback*, 29 (2), 121-133.
- Herbs, D., Gevirtz, R. N., & Jacobs, D. (1994). The effect of heart rate pattern biofeedback for the treatment of essential hypertension. *Biofeedback and Self-regulation*, 19(3), 281 Abstract.
- Ironson, G., Taylor, C. B., Boltwood, M., Bartzokis, T., Dennis, C., Chesney, M., Spitzer, S., & Segall, G. M. (1992). Effects of anger on left ventricular ejection fraction in coronary artery disease. *American Journal of Cardiology*, 70 (3), 281-285.
- Kleiger, R. E., Miller, J. P., Bigger, J. T., et al., and the Multicenter Post-Infarction Research Group. (1987). Decreased heart rate variability and its association with increased mortality after acute myocardial infarction. *American Journal of Cardiology*, 59, 256-262.
- Lacey, J. I., (1967). Somatic response patterning and stress: Some revisions of activation theory. In M. H. Appley & R. Trumbull (Eds.), *Psychological stress: Issues in research* (pp 14-42). New York: Appleton-Century-Crofts.
- Lacey, J. I., & Lacey, B. C. (1964). *Cardiac deceleration and simple visual reaction in a fixed foreperiod experiment*. Paper presented at the meeting of the Society for Psychophysiological Research, Washington, D.C.
- Lacey, J. I., & Lacey, B. C. (1978). Two-way communication between the heart and the brain: Significance of time within the cardiac cycle. *American Psychologist*, 33(2), 99-113.
- Lehrer, P., & Carrington, P. (2003). Relaxation, autogenic training, and meditation. In D. Moss, A. McGrady, T. Davies, & I. Wickramasekera (Eds.), *Handbook of mind-body medicine for primary care* (pp. 137-149). Thousand Oaks, CA: Sage.
- Lehrer, P.M., Vaschillo, E.V., & Vaschillo, B. (in press). Heartbeat synchronizes with respiratory rhythm only under specific circumstances. *Chest*.
- Lehrer, P., Vaschillo, E., Vaschillo, B., Lu, S-E, Scardella, A., Siddique, M., & Habib, R. (2004). Biofeedback treatment for asthma. *Chest*, 126, 352-361.
- MacLean, B. (in press for 2004). The heart and the breath of love. *Biofeedback*, 32 (4).
- McCraty, R., Atkinson, M, Tiller, W A. (1995). The effects of emotion on short term heart rate variability using power spectrum analysis. *American Journal of Cardiology*, 76.

Xiangcai, X. (2000). *Qigong for treating common ailments: The essential guide to self-healing*. Boston, MA: YMAA Publication Center.

¹ The author has developed software screens for the Thought Technology Infinity biofeedback system, pursuing each of the training strategies described here, and rewarding the subject automatically for achieving the training criteria formulated for each strategy.
