

## A Basic Biofeedback Primer

**Rich Norman<sup>(1)</sup>, Cengiz Mordeniz<sup>(3)</sup>, Leonardo Mendolicchio<sup>(1,2)</sup>, Enrico Pierangeli<sup>(1)</sup>, Paolo Pannarale<sup>(4)</sup>, Franco Orsucci<sup>(5)</sup>, Elio Conte<sup>(1)</sup>**  
School of Advanced International Studies on Applied Theoretical and Non Linear  
Methodologies of Physics , Bari Italy

### PROFILES OF THE AUTHORS

<sup>(1)</sup>Rich Norman, Researcher in Neurology and Psychology at the School of Advanced International Studies on Applied Theoretical and Non Linear Methodologies of Physics, Bari, Italy

<sup>(2)</sup>Leonardo Mendolicchio, psychiatrist, Director Villa Miralago Clinic for the therapy of the eating disorders, Varese, Italy;

<sup>(3)</sup>Cengiz Mordeniz, Associated professor of anesthesiology, Namık Kemal Üniversitesi and Tekirdağ Laboratory of Psychophysiology, Turkey;

<sup>(1)</sup>Enrico Pierangeli, Neurosurgeon and former professor of neurosurgery University of Bari;

<sup>(4)</sup>Paolo Pannarale, Hospital neurologist, Bari;

<sup>(5)</sup>Franco Orsucci, psychiatrist, professor of psychiatry, University College London; Lead Consultant, CPFT – Cambridge University Health Partners Director, Institute for Complexity Studies of Rome-Italy.

Contact: Professor Elio Conte, [elio.conte@fastwebnet.it](mailto:elio.conte@fastwebnet.it)

### **Abstract:**

*Biofeedback is a longstanding technique whereby voluntary control may be asserted over many seemingly unconscious physiologic and autonomic processes. Neurofeedback is a particular branch of biofeedback using real time information derived through the active monitoring of brain states to allow development of therapeutically efficacious informationally rich results. Our facility and staff are expert in the use of biofeedback as both a direct therapeutic aid, and assessment tool. This document will briefly detail the historical development and underlying principles of bio- and neuro-feedback techniques and their substantial theoretical and experimental basis.*

Biofeedback/Neurofeedback is now well defined by the scientific community. The Association for Applied Psychophysiology and Biofeedback (AAPB), Biofeedback Certification International Alliance (BCIA), and the International Society for Neurofeedback and Research (ISNR), formulated this definition of biofeedback in 2008:

*Biofeedback is a process that enables an individual to learn how to change physiological activity for the purposes of improving health and performance. Precise instruments measure physiological activity such as brainwaves, heart function, breathing, muscle*

*activity, and skin temperature. These instruments rapidly and accurately 'feed back' information to the user. The presentation of this information — often in conjunction with changes in thinking, emotions, and behavior — supports desired physiological changes. Over time, these changes can endure without continued use of an instrument.*

**History, current use, evaluation and empirical substantiation:** Biofeedback has been a mainstay within many cultures and cultural practices for thousands of years, and is still used today in traditional forms such as Yoga and Pranayama. In western science, the progression of biofeedback can be roughly traced as follows: Claude Bernard in 1865 derived the concept of homeostasis [1]. In 1885, J. R. Tarchanoff demonstrated control of heart rate could be direct (cortical-autonomic) [2]. In 1901, J. H. Bair showed that skeletal muscles are self-regulated [3]. Alexander Graham Bell attempted to teach the deaf to speak using two devices — the phonograph, and a manometric flame. The former translated sound vibrations to show their acoustic waveforms, while the latter allowed sound to be displayed as patterned light [4]. Mathematician Norbert Wiener developed cybernetic theory, that proposed that systems are controlled by monitoring their results [5]. The participants at a 1969 conference coined the term biofeedback from Wiener's ideas. The conference marked the founding of the Bio-Feedback Research Society [6]. In the first experimental demonstration of biofeedback, Shearn used these procedures with heart rate. Effects of the perception of autonomic nervous system activity were initially explored by George Mandler's group in 1958. In 1965, Maia Lisina trained subjects to change blood vessel diameter, eliciting and displaying reflexive blood flow changes [7]. In 1974, H.D. Kimmel trained subjects to sweat using the galvanic skin response. (Text in paragraph above condensed from [8]).

Neurofeedback has the following additional historical lineage: In 1924, German psychiatrist Hans Berger attached electrodes to a patient's scalp and detected a small current using a galvanometer. During the years 1929-1938 he published 14 reports about his studies of EEGs. In 1932 G. Dietsch applied Fourier analysis to seven records of EEG and became the first researcher of QEEG (quantitative EEG) [9]. Joe Kamiya popularized neurofeedback in the 1960s. Later, Barbara Brown wrote several books on biofeedback. The work of Barry Sterman, Joel F. Lubar and others has impacted the study of beta training, pertaining to sensorimotor rhythmic EEG activity [10]. This training has been used in the treatment of epilepsy, attention deficit disorder and hyperactive disorder [11-13]. The sensorimotor rhythm (SMR) is rhythmic activity between 12 and 16 hertz that can be recorded from an area near the sensorimotor cortex. SMR is found in waking states and is very similar if not identical to the sleep spindles that are recorded in the second stage of sleep. Alpha-theta training has been applied to patients with alcoholism, other addictions and to cases of anxiety [14]. This training differs greatly from the high frequency beta and SMR training and is reminiscent of the original alpha training of Elmer Green and Joe Kamiya [14]. Beta and SMR training are a directly physiological approach, strengthening sensorimotor inhibition in the cortex and inhibiting alpha patterns. Alpha-theta training is different and derives from the psychotherapeutic model and so involves the accessing of painful or repressed memories through the alpha-theta state [15].

(Text in paragraph above condensed from [16]).

The substantial efficacy and limits of bio- and neuro-feedback are now well established. In [17] extensive literature was reviewed and the results rated on a 5 tier scale. The results can be quickly summarized in part as follows, for the following applications:

Alcoholism / Substance Abuse Level 3: Probably Efficacious; Anxiety Level 4: Efficacious; Arthritis Level 3: Probably Efficacious; Asthma Level 2: Possibly Efficacious; Attention Deficit Hyperactivity Disorder (ADHD) Level 4: Efficacious; Autism Level 2: Possibly Efficacious; Cerebral Palsy Level 2: Possibly Efficacious; Chronic Obstructive Pulmonary Disease (COPD) Level 2: Possibly Efficacious; Chronic Pain Level 4: Efficacious; Coronary Artery Disease Level 2: Possibly Efficacious; Cystic Fibrosis Level 2: Possibly Efficacious; Depressive Disorders Level 2: Possibly Efficacious; Diabetes Mellitus Level 3: Probably Efficacious; Epilepsy Level 4: Efficacious; Erectile Dysfunction Level 2 Efficacy – Possibly Efficacious; Fecal Disorders in Children Level 3: Probably Efficacious; Fecal Incontinence: Adults Level 3: Probably Efficacious; Constipation: Adults Level 4: Efficacious; Fibromyalgia/Chronic Fatigue Syndrome Level 2: Possibly Efficacious; Hand Dystonia Level 2: Possibly Efficacious; Headache – Pediatric Level 3: Probably Efficacious; Headache – Adult Level 4: Efficacious; Hypertension Level 4: Efficacious; Insomnia Level 3: Probably Efficacious; Motion Sickness Level 4: Efficacious; Post-Traumatic Stress Disorder Level 2: Possibly Efficacious; Raynaud’s Disease Level 4: Efficacious; Repetitive Strain Injury Level 2: Possibly Efficacious; Respiratory Failure: Mechanical Ventilation Level 2: Possibly Efficacious; Stroke (Cardiovascular Accident) Level 2: Possibly Efficacious; Tinnitus Level 2: Possibly Efficacious; Temporomandibular Disorder (TMD) Level 4: Efficacious; Traumatic Brain Injury (TBI) Level 3: Probably Efficacious; Urinary Incontinence in Females Level 5: Efficacious and Specific; Urinary Incontinence in Males Level 3: Probably Efficacious; Urinary Incontinence in Children Level 2: Possibly Efficacious; Vulvar Vestibulitis (Vulvodynia) Level 3: Probably Efficacious.

Research on neurofeedback demonstrates it as a valid and effective therapy. It has been used for pain, addiction, aggression, anxiety, autism, depression, schizophrenia, epilepsy, headaches, insomnia, Tourette syndrome, and brain damage from stroke and trauma [18-33]. (Text condensed from [16]).

**General parameters, equipment and approach** (condensed from [8, 16]):

Electromyograph

An electromyograph (EMG) uses electrodes to articulate muscle action potentials which cause muscular contractions. In addition to surface electrodes, intramuscular wires or needles may be used to capture EMG signals. Raw EMG signals are typically processed in three ways: rectification, filtering, and integration. EMG biofeedback is used in treating anxiety and worry, chronic pain, essential hypertension, headache (migraine, mixed headache, and tension-type headache), low back pain, physical rehabilitation (cerebral palsy, incomplete spinal cord lesions, and stroke), temporomandibular joint

dysfunction (TMD), torticollis, and fecal incontinence, urinary incontinence, and pelvic pain.

### Feedback thermometer

A feedback thermometer detects skin temperature with a temperature-sensitive resistor attached to a finger or toe. Skin temperature mainly reflects arteriole diameter. Hand-warming involves arteriole vasodilation produced by a beta-2 adrenergic hormonal mechanism. Hand-cooling involves arteriole vasoconstriction produced by the increased firing of sympathetic C-fibers.

Temperature biofeedback is used in treating chronic pain, edema, migraine and tension headache, essential hypertension, Raynaud's disease, anxiety, and stress.

### Electrodermograph

An electrodermograph (EDG) measures skin electrical activity directly (skin conductance and skin potential) and indirectly (skin resistance) using electrodes placed over the digits or hand and wrist. Orienting responses to unexpected stimuli, arousal and worry, and cognitive activity can increase eccrine sweat gland activity, increasing the conductivity of the skin for electric current.

In *skin conductance*, an electrodermograph applies current across the skin and measures its flow. When anxiety increases sweat production, conductance increases. Skin conductance is measured in microsiemens. In galvanic skin response (GSR), an electrodermograph applies a current across the skin and measures the result [35].

Electrodermal biofeedback is used in treating anxiety disorders, hyperhidrosis (excessive sweating), and stress. Electrodermal biofeedback is used as an adjunct to psychotherapy to increase client awareness of their emotions. In addition, electrodermal measures have long served as one of the central tools in polygraphy because they reflect changes in anxiety or emotional activation.

### EEG:

The electroencephalograph (EEG) measures electrical activity of the brain from sites located over the human cortex. The EEG shows the amplitude of electrical activity at each cortical site, the amplitude and relative power of various wave forms at each site, and the degree to which each cortical site fires in conjunction with other cortical sites (coherence and symmetry) [36].

The EEG uses precious metal electrodes to detect a voltage between at least two electrodes located on the scalp. The EEG records both excitatory postsynaptic potentials (EPSPs) and inhibitory postsynaptic potentials (IPSPs) that largely occur in dendrites in pyramidal cells located in macrocolumns, several millimeters in diameter, in the upper cortical layers. Neurofeedback monitors both slow and fast cortical potentials [37].

Slow cortical potentials are gradual changes in the membrane potentials of cortical dendrites that last from 300 ms to several seconds. These potentials include the contingent negative variation (CNV), readiness potential, movement-related potentials (MRPs), and P300 and N400 potentials [38].

Fast cortical potentials range from 0.5 Hz to 100 Hz [39]. The main frequency ranges include delta, theta, alpha, the sensorimotor rhythm, low beta, high beta, and gamma. The thresholds or boundaries defining the frequency ranges vary considerably among professionals. Fast cortical potentials can be described by their predominant frequencies, but also by whether they are synchronous or asynchronous wave forms. Synchronous wave forms occur at regular periodic intervals, whereas asynchronous wave forms are irregular [37].

The synchronous delta rhythm ranges from 0.5 to 3.5 Hz. Delta is the dominant frequency from ages 1 to 2, and is associated in adults with deep sleep and brain pathology like trauma and tumors, and learning disability.

The synchronous theta rhythm ranges from 4 to 7 Hz. Theta is the dominant frequency in healthy young children and is associated with drowsiness or starting to sleep, REM sleep, hypnagogic imagery (intense imagery experienced before the onset of sleep), hypnosis, attention, and processing of cognitive and perceptual information.

The synchronous alpha rhythm ranges from 8 to 13 Hz and is defined by its waveform and not by its frequency. Alpha activity can be observed in about 75% of awake, relaxed individuals and is replaced by low-amplitude desynchronized beta activity during movement, complex problem-solving, and visual focusing. This phenomenon is called alpha blocking.

The synchronous sensorimotor rhythm (SMR) ranges from 12 to 15 Hz and is located over the sensorimotor cortex (central sulcus). The sensorimotor rhythm is associated with the inhibition of movement and reduced muscle tone.

The beta rhythm consists of asynchronous waves and can be divided into low beta and high beta ranges (13–21 Hz and 20–32 Hz). Low beta is associated with activation and focused thinking. High beta is associated with anxiety, hypervigilance, panic, peak performance, and worry.

EEG activity from 36 to 44 Hz is also referred to as gamma. Gamma activity is associated with perception of meaning and meditative awareness [8].

Neurotherapists use EEG biofeedback when treating addiction, attention deficit hyperactivity disorder (ADHD), learning disability, anxiety disorders (including worry, obsessive-compulsive disorder and post traumatic stress disorder), depression, migraine, and generalized seizures [8].

## Photoplethysmograph

A photoplethysmograph (PPG) measures the relative blood flow through a digit using a photoplethysmographic (PPG) sensor attached by a Velcro band to the fingers or to the temple to monitor the temporal artery. An infrared light source is transmitted through or

reflected off the tissue, detected by a phototransistor, and quantified in arbitrary units. Less light is absorbed when blood flow is greater, increasing the intensity of light reaching the sensor [40].

A photoplethysmograph can measure blood volume pulse (BVP), which is the phasic change in blood volume with each heartbeat, heart rate, and heart rate variability (HRV), which consists of beat-to-beat differences in intervals between successive heartbeats [41, 42].

A photoplethysmograph can provide useful feedback when temperature feedback shows minimal change. This is because the PPG sensor is more sensitive than a thermistor to minute blood flow changes. The photoplethysmograph is used to supplement temperature biofeedback when treating chronic pain, edema, headache (migraine and tension-type headache), essential hypertension, Raynaud's disease, anxiety, and stress [8].

### Electrocardiogram

The electrocardiogram (ECG) uses electrodes placed on the torso, wrists, or legs, to measure the electrical activity of the heart and measures the interbeat interval (distances between successive R-wave peaks in the QRS complex). The interbeat interval, divided into 60 seconds, determines the heart rate at that moment. The statistical variability of that interbeat interval is heart rate variability [43].

Heart Rate Variability biofeedback is used when treating asthma, COPD, depression, anxiety, fibromyalgia, heart disease, and unexplained abdominal pain [8] [44-50].

HRV data from both polyplethysmographs and electrocardiograms are analyzed via mathematical transformations such as the commonly-used Fast Fourier Transform (FFT). The FFT splits the HRV data into a power spectrum, revealing the waveform's constituent frequencies [40]. Among those constituent frequencies, high-frequency (HF) and low-frequency (LF) components are defined as above and below .15 Hz, respectively. As a rule of thumb, the LF component of HRV represents sympathetic activity, and the HF component represents parasympathetic activity. The two main components are often represented as a LF/HF ratio and used to express sympathovagal balance [40]. Some researchers specify a third, medium-frequency (MF) component from .08 Hz to .15 Hz, which has been shown to increase in power during times of appreciation [51].

### Further Cardiovascular specificity:

Emotions are intimately linked to heart health, which is linked to physical and mental health. In general, good mental and physical health are correlated with positive emotions and high heart rate variability (HRV) modulated by mostly high frequencies [52-54]. High HRV has been correlated with increased executive functioning skills such as memory and reaction time [25]. Biofeedback that increased HRV and shifted power toward HF (high-frequencies) has been shown to lower blood pressure [55]. On the other hand, LF (low-frequency) power in the heart is associated with sympathetic vagal

activity, which is known to increase the risk of heart attack [56]. LF-dominated HRV power spectra are also directly associated with higher mortality rates in healthy individuals, and among individuals with mood disorders [8] [57-59]. Anger and frustration increase the LF range of HRV [60]. Other studies have shown anger to increase the risk of heart attack [61].

Because emotions have such an impact on cardiac function, which cascades to numerous other biological processes, emotional regulation techniques are able to effect practical, psychophysiological change [55]. McCraty et al. discovered that feelings of gratitude increased HRV and moved its power spectrum toward the MF (mid-frequency) and HF (high-frequency) ranges, while decreasing LF (low-frequency) power [60].

(The above section text, "General parameters, equipment and approach," was condensed from sources [8] and [16]).

### **Conclusion:**

Biofeedback and Neurofeedback are techniques which allow what are ordinarily unconscious and autonomic processes to be consciously mediated, and so, provide non invasive therapeutic options the benefits of which extend well past initial training sessions. Due to the longstanding commitment of our facility and staff to the utilization of this technology, and our specific nonlinear and linear mathematical analyses, we are in a position to gain substantial new ground in this area. It is through the understanding and interpretation of carefully collected data through subsequent linear and nonlinear mathematical analysis, that the future potential of this technology will be most fruitfully made available.

### **References:**

- [1] Bernard C (1957) [First published 1865]. *An Introduction to the study of experimental medicine*. Mineola, N.Y: Dover.
- [2] Tarchanoff, JR (1885). "Voluntary acceleration of the heart beat in man." *Pfluger's Archive der gesamten Physiologie***35**: 109–135. doi:10.1007/BF01612726.
- [3] Bair, JH (1901). "Development of voluntary control". *Psychological Review* **8** (5): 474–510. doi:10.1037/h0074157.
- [4] Bruce, Robert C. (1990). *Bell: Alexander Graham Bell and the conquest of solitude*. Ithaca, N.Y: Cornell University Press.
- [5] Wiener, Norbert (2007). *Cybernetics Or Control And Communication In The Animal*

*And The Machine*. Kessinger Publishing, LLC.

[6] Moss D (1999). "Biofeedback, mind-body medicine, and the higher limits of human nature". *Humanistic and transpersonal psychology: a historical and biographical sourcebook*. Westport, Conn: Greenwood Press.

[7] Lisina MI (1965). "The role of orientation in the transformation of involuntary reactions into voluntary ones". In Voronin IG; Leontiev AN; Luria AR; Sokolov EN & Vinogradova OB. *Orienting reflex and exploratory behavior*. Washington, DC: American Institute of Biological Studies. pp. 339–44.

[8] Retrieved from <https://en.wikipedia.org/wiki/Biofeedback>

[9] Kaiser David A (2005). "Basic Principles of Quantitative EEG". *Journal of Adult Development* **12** (2/3).

[10] Serman, M.B.; Clemente, C.D. (1962). "Forebrain inhibitory mechanisms: cortical synchronization induced by basal forebrain stimulation". *Exp Neurol* **6** (2): 91–102. doi:10.1016/0014-4886(62)90080-8. PMID 13916975.

[11] Serman, M.B.; Friar, L. (1972). "Suppression of seizures in an epileptic following sensorimotor EEG feedback training". *Electroencephalogr Clin Neurophysiol* **33** (1): 89–95. doi:10.1016/0013-4694(72)90028-4. PMID 4113278.

[12] Serman, M.B. (2000). "Basic concepts and clinical findings in the treatment of seizure disorders with EEG operant conditioning". *Clin Electroencephalogr* **31** (1): 45–55. doi:10.1177/155005940003100111. PMID 10638352.

[13] Lubar, J.F.; Swartwood, M.O.; Swartwood, J.N.; O'Donnell, P.H. (1995). "Evaluation of the effectiveness of EEG neurofeedback training for ADHD in a clinical setting as measured by changes in TOVA scores, behavioral ratings, and WISC-R performance" (PDF). *Applied Psychophysiology and Biofeedback* **20** (1): 83–99. doi:10.1007/bf01712768. Retrieved 2007-12-05.

[14] Sokhadze, Tato M.; Cannon, Rex L.; Trudeau, David L. (Mar 2008). "EEG Biofeedback as a Treatment for Substance Use Disorders: Review, Rating of Efficacy, and Recommendations for Further Research". *Appl Psychophysiol Biofeedback* **33** (1): 1–28. doi:10.1007/s10484-007-9047-5. PMC 2259255. PMID 18214670.

[15] Reel, Justine J. (2013). *Eating Disorders: An Encyclopedia of Causes, Treatment, and Prevention*. ABC-CLIO. p. 300.

[16] Retrieved from: <https://en.wikipedia.org/wiki/Neurofeedback>

[17] Yucha, C; Montgomery D (2008). *Evidence-based practice in biofeedback and neurofeedback* (PDF). Wheat Ridge, CO: AAPB. Archived from the original (PDF) on

2010-10-09. [https://www.aapb.org/files/public/Yucha-Gilbert\\_EvidenceBased2004.pdf](https://www.aapb.org/files/public/Yucha-Gilbert_EvidenceBased2004.pdf)

[18] Karidis, Arlene. "Neurofeedback – The Scientific Evidence Grows". *Perth Brain Centre*. Perth Brain Centre.

[19] Christopher deCharms, R., et al. "Control over brain activation and pain learned by using real-time functional MRI." *Proceedings of the National Academy of Sciences of the United States of America* 102.51 (2005): 18626-18631.

[20] Peniston EG, Kulkosky PJ (1989). "Alpha-theta brainwave training and beta-endorphin levels in alcoholics." *Alcoholism: Clinical and Experimental Research* 13 (2): 271–279. doi:10.1111/j.1530-0277.1989.tb00325.x. PMID 2524976.

[21] William C. Scott; David Kaiser; Siegfried Othmer; Stephen I. Sideroff (2005). "Effects of an EEG Biofeedback Protocol on a Mixed Substance Abusing Population." *The American Journal of Drug and Alcohol Abuse* 31 (3): 455–469. doi:10.1081/ADA-200056807.

[22] Rostami R, Dehghani-Arani F (2015). "Training as a New Method in Treatment of Crystal Methamphetamine Dependent Patients: A Preliminary Study." *Appl Psychophysiol Biofeedback*. 40(3): 151–61. doi:10.1007/s10484-015-9281-1. PMID 25894106.

[23] Dehghani-Arani F; Rostami R; Masoud Nostratabadi. (2010). "Effectiveness of Neurofeedback Training as a Treatment for Opioid Dependent Patients". *Clinical EEG and Neuroscience*. 41 (3): 170–177. doi:10.1177/155005941004100313. PMID 20722354.

[24] Arani, FD; Rostami, R; Nostratabadi, M (Jul 2010). "Effectiveness of neurofeedback training as a treatment for opioid-dependent patients." *Clin EEG Neurosci* 41 (3): 170–7. doi:10.1177/155005941004100313. PMID 20722354.

[25] Coben R, Linden M, Myers TE (2010). "Neurofeedback for autistic spectrum disorder: a review of the literature." *Applied Psychophysiology and Biofeedback* 35 (1): 83–105. doi:10.1007/s10484-009-9117-y. PMID 19856096.

[26] Linden DE, Habes I, Johnston SJ, Linden S, Tatineni R, Subramanian L, Sorger B, Healy D, Goebel R (2012). "Real-time self-regulation of emotion networks in patients with depression." *PLoS ONE* 7 (6): e38115. doi:10.1371/journal.pone.0038115. PMID 22675513.

[27] Surmeli, Tanju (2012), "Living Health Center for Research and Education, Istanbul, Turkey."(PDF), *Schizophrenia and the efficacy of qEEG-guided neurofeedback treatment: a clinical case series*, California State University, San Bernardino

[28] Surmeli, Tanju (2012), "Schizophrenia and the efficacy of qEEG-guided

neurofeedback treatment: a clinical case series", *Clin EEG Neurosci* (US National Library of Medicine National Institutes of Health) **43**: 133–44, doi:10.1177/1550059411429531, PMID 22715481

[29] Tan G, Thornby J, Hammond DC, Strehl U, Canady B, Arnemann K, Kaiser DA (2009). "Meta-analysis of EEG biofeedback in treating epilepsy." *Journal of Clinical EEG & Neuroscience* **40** (3): 173–179. doi:10.1177/155005940904000310. PMID 19715180.

[30] Jeffrey A. Carmen (2005). "Passive Infrared Hemoencephalography: Four Years and 100 Migraines." *Journal of Neurotherapy* **8** (3): 23–51. doi:10.1300/J184v08n03\_03.

[31] Cortoos A, De Valck E, Arns M, Breteler MH, Cluydts R (2010). "An exploratory study on the effects of tele-neurofeedback and tele-biofeedback on objective and subjective sleep in patients with primary insomnia." *Applied Psychophysiology and Biofeedback* **35** (2): 125–134. doi:10.1007/s10484-009-9116-z. PMID 19826944.

[32] Messerotti Benvenuti S, Buodo G, Leone V, Palomba D (2011). "Neurofeedback training for tourette syndrome: an uncontrolled single case study." *Applied Psychophysiology and Biofeedback* **36** (4): 281–288. doi:10.1007/s10484-011-9169-7. PMID 21915704.

[33] Mihara M, Hattori N, Hatakenaka M, Yagura H, Kawano T, Hino T, Miyai I (2013). "Near-infrared spectroscopy-mediated neurofeedback enhances efficacy of motor imagery-based training in poststroke victims: a pilot study." *Stroke* **44** (4): 1091–1098. doi:10.1161/STROKEAHA.111.674507. PMID 23404723.

[34] Thornton KE, Carmody DP (2008). "Efficacy of traumatic brain injury rehabilitation: interventions of QEEG-guided biofeedback, computers, strategies, and medications." *Applied Psychophysiology and Biofeedback* **33** (2): 101–124. doi:10.1007/s10484-008-9056-z. PMID 18551365.

[35] Norman, R., Conte, E. Mendolicchio, L., Mordeniz, C., Pierangeli, E., Pannarale, P., Orsucci, F. (2016) On The Methodological Profile of GSR Studies in the light of the Recent Advances Obtained in the Knowledge of Its Neurological Correlates. *viXra* <http://viXra.org/abs/1606.0095?ref=8892102>

[36] Kropotov, J. D. (2009). *Quantitative EEG, event-related potentials and neurotherapy*. San Diego, CA: Academic Press.

[37] Thompson, M., & Thompson, L. (2003). *The biofeedback book: An introduction to basic concepts in applied psychophysiology*. Wheat Ridge, CO: Association for Applied Psychophysiology and Biofeedback.

[38] Stern, R. M., Ray, W. J., & Quigley, K. S. (2001). *Psychophysiological recording* (2nd ed.). New York: Oxford University Press.

- [39] LaVaque, T. J. (2003). Neurofeedback, Neurotherapy, and quantitative EEG. In D. Moss, A. McGrady, T. Davies, & I. Wickramasekera (Eds), *Handbook of mind-body medicine for primary care* (pp. 123-136). Thousand Oaks, CA: Sage.
- [40] Combatalade, D. (2009). *Basics of heart rate variability applied to psychophysiology*. Montreal, Canada: Thought Technology Ltd.
- [41] Lehrer, P. M. (2007). Biofeedback training to increase heart rate variability. In P. M. Lehrer, R. M. Woolfolk, & W. E. Sime (Eds.). *Principles and practice of stress management* (3rd ed.). New York: The Guilford Press.
- [42] Peper E.; Harvey R.; Lin I.; Tylova H.; Moss D. (2007). "Is there more to blood volume pulse than heart rate variability, respiratory sinus arrhythmia, and cardio-respiratory synchrony?". *Biofeedback* **35** (2): 54–61.
- [43] Berntson, G. G., Quigley, K. S., & Lozano, D. (2007). Cardiovascular psychophysiology. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson, (Eds.). *Handbook of psychophysiology* (3rd ed.). New York: Cambridge University Press.
- [44] Lehrer P. M.; Vaschillo E.; Vaschillo B.; Lu S. E.; Scardella A.; Siddique M.; et al. (2004). "Biofeedback as a treatment for asthma". *Chest* **126** (2): 352–361. doi:10.1378/chest.126.2.352
- [45] Giardino N. D.; Chan L.; Borson S. (2004). "Combined heart rate variability and pulse oximetry biofeedback for chronic obstructive pulmonary disease: Preliminary findings". *Applied Psychophysiology and Biofeedback* **29** (2): 121–133. doi:10.1023/B:APBI.0000026638.64386.89
- [46] Karavidas M. K.; Lehrer P. M.; Vaschillo E. G.; Vaschillo B.; Marin H.; Buyske S.; et al. (2007). "Preliminary results of an open-label study of heart rate variability biofeedback for the treatment of major depression". *Applied Psychophysiology and Biofeedback* **32** (1): 19–30. doi:10.1007/s10484-006-9029-z
- [47] Trousselard, M.; Canini, F.; Claverie, D.; Cungi, C.; Putois, B.; Franck, N. (2015-09-07). "Cardiac Coherence Training to Reduce Anxiety in Remitted Schizophrenia, a Pilot Study". *Applied Psychophysiology and Biofeedback* **41** (1): 61–69. doi:10.1007/s10484-015-9312-y
- [48] Hassett A. L.; Radvanski D. C.; Vaschillo E. G.; Vaschillo B.; Sigal L. H.; Karavidas M. K.; et al. (2007). "A pilot study of heart rate variability (HRV) biofeedback in patients with fibromyalgia". *Applied Psychophysiology and Biofeedback* **32** (1): 1–10. doi:10.1007/s10484-006-9028-0
- [49] Cowan M. J.; Pike K. C.; Budzynski H. K. (2001). "Psychosocial nursing therapy following sudden cardiac arrest: Impact on two-year survival". *Nursing Research* **50** (2):

68–76. doi:10.1097/00006199-200103000-00002

[50] Humphreys P.; Gevirtz R. (2000). "Treatment of recurrent abdominal pain: Components analysis of four treatment protocols". *Journal of Pediatric Gastroenterology and Nutrition* **31** (1): 47–51. doi:10.1097/00005176-200007000-00011

[51] McCraty, Rollin; Atkinson, Mike; Tiller, William A.; Rein, Glen; Watkins, Alan D. "The effects of emotions on short-term power spectrum analysis of heart rate variability". *The American Journal of Cardiology* **76** (14): 1089–1093. doi:10.1016/s0002-9149(99)80309-9

[52] Thayer, Julian F.; Hansen, Anita L.; Saus-Rose, Evelyn; Johnsen, Bjorn Helge (8 May 2009). "Heart Rate Variability, Prefrontal Neural Function, and Cognitive Performance: The Neurovisceral Integration Perspective on Self-regulation, Adaptation, and Health". *Annals of Behavioral Medicine* **37** (2): 141–153. doi:10.1007/s12160-009-9101-z.

[53] McCraty, Rollin; Atkinson, Mike; Tomasino, Dana; Bradley, Raymond (2009). "The Coherent Heart". *Integral Review* **5** (2): 41–46.

[54] McCraty, Rollin; Atkinson, Mike; Tomasino, Dana; Bradley, Raymond (2009). "The Coherent Heart". *Integral Review* **5** (2): 22–26.

[55] BARRIOS-CHOPLIN, BOB; McCRATY, ROLLIN; CRYER, BRUCE (July 1997). "AN INNER QUALITY APPROACH TO REDUCING STRESS AND IMPROVING PHYSICAL AND EMOTIONAL WELLBEING AT WORK". *Stress Medicine* **13** (3): 193–201. doi:10.1002/(SICI)1099-1700(199707)13:3<193::AID-SMI744>3.0.CO;2-I.

[56] Lown, B; DeSilva, RA (22 May 1978). "Roles of psychologic stress and autonomic nervous system changes in provocation of ventricular premature complexes.". *The American journal of cardiology* **41** (6): 979–85. doi:10.1016/0002-9149(78)90850-0.PMID 665521.

[57] Tsuji, H.; Larson, M. G.; Venditti, F. J.; Manders, E. S.; Evans, J. C.; Feldman, C. L.; Levy, D. (1 December 1996). "Impact of Reduced Heart Rate Variability on Risk for Cardiac Events: The Framingham Heart Study". *Circulation* **94** (11): 2850–2855. doi:10.1161/01.CIR.94.11.2850.

[58] Tsuji, H.; Venditti, F. J.; Manders, E. S.; Evans, J. C.; Larson, M. G.; Feldman, C. L.; Levy, D. (1 August 1994). "Reduced heart rate variability and mortality risk in an elderly cohort. The Framingham Heart Study". *Circulation* **90** (2): 878–883. doi:10.1161/01.CIR.90.2.878.

[59] Kemp, Andrew H.; Quintana, Daniel S. (September 2013). "The relationship between mental and physical health: Insights from the study of heart rate variability". *International Journal of Psychophysiology* **89**(3): 288–

296.doi:10.1016/j.ijpsycho.2013.06.018.

[60] McCraty, Rollin; Atkinson, Mike; Tiller, William A.; Rein, Glen; Watkins, Alan D. (November 1995). "The effects of emotions on short-term power spectrum analysis of heart rate variability". *The American Journal of Cardiology* **76** (14): 1089–1093.doi:10.1016/S0002-9149(99)80309-9.

[61] Mittleman, MA; Maclure, M; Sherwood, JB; Mulry, RP; Tofler, GH; Jacobs, SC; Friedman, R; Benson, H; Muller, JE (1 October 1995). "Triggering of acute myocardial infarction onset by episodes of anger. Determinants of Myocardial Infarction Onset Study Investigators.". *Circulation* **92** (7): 1720–5.PMID 7671353.