

# Biofeedback: An overview in the context of heart-brain medicine

## ■ ABSTRACT

Biofeedback involves the monitoring and use of physiologic information to teach patients to modify specific physiologic functions. Common modalities for biofeedback include surface electromyography, respiration rate and depth, skin surface temperature, cardiovascular reactivity, and electrodermal response. Clinical biofeedback therapy broadly involves either the direct feedback learning model or the therapeutic/stress-management/biofeedback model, which emphasizes the need to understand each patient as an individual. Biofeedback interventions have been deemed efficacious or probably efficacious in treating a number of medical disorders, and are increasingly embraced by the public as well as by health care providers and payors.

**C**linical biofeedback therapy is one of the many new approaches in health care aimed at helping individuals take responsibility for their well-being, including responsibility for the cognitive, emotional, and behavioral changes needed to effect healthy physiologic change. This article provides a brief survey of biofeedback therapy by defining what biofeedback involves, reviewing the various modalities that it can serve to monitor, discussing major models of biofeedback therapy, and outlining criteria for evaluating the efficacy of biofeedback interventions.

## ■ BIOFEEDBACK: BOTH PROCESS AND INSTRUMENTATION

*Biofeedback* refers to both a process and the instrumentation used in that process.

The process is one of learning to use physiologic information that is monitored and “fed back” through

biofeedback instruments. The term dates from 1969, when it was coined to describe laboratory procedures that had been developed in the 1940s in which research subjects learned to modify heart rate, blood flow, and other physiologic functions that were not normally thought of as being subject to conscious control. Feedback itself has been present through much of human history, particularly through the use of mirrored surfaces to practice the expression of emotion.<sup>1</sup>

Biofeedback instruments monitor one or more physiologic processes, measure what is monitored and transform that measurement into auditory and/or visual signals, and present what is monitored and measured in a simple, direct, and immediate way. Biofeedback equipment typically is noninvasive. The instruments provide continuous monitoring and transformation of physiologic data into understandable feedback for the patient being monitored. Current computerized instruments can provide simultaneous displays and recording of multiple channels of physiologic information. The goal is to enable the individual being monitored to change some physiologic process, guided by the information provided by the biofeedback equipment. How many training sessions are necessary varies with the individual and the disorder, ranging from a few to 50 or more. Our experience is that the great majority of patients obtain benefit in 8 to 12 sessions.

## ■ MULTIPLE MODALITIES FOR MONITORING

Multiple modalities can be monitored via biofeedback. Surface electromyography is perhaps the most commonly used instrumentation. Other commonly used measures in a psychophysiological/biofeedback assessment are respiration rate and depth, skin surface temperature (particularly at the fingertips), cardiovascular reactivity (particularly heart rate and blood pressure), and electrodermal response.<sup>2</sup>

Feedback of real-time physiologic data is limited only by one's creativity and technological capabilities. Most of the early noncomputerized equipment provided feedback through the onset and offset of

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sounds, the changing of tones and volume, the turning on and off of lights, and digital numeric displays indicating both the direction of change and absolute values (such as digital peripheral temperature). Current computerized equipment uses such feedback features as computer games, which the patient “wins” by reaching a goal (such as a systolic blood pressure level below 130 mm Hg), mandalas that can be filled in with colors of the patient’s choosing as he or she progresses in the desired direction, and complex computer-generated figures and graphs.

Electroencephalographic biofeedback (neurofeedback) has become a separate area of study and application, with particular use in the treatment of attention deficit disorder. A baseline electroencephalogram is used in neurofeedback assessment to identify abnormal patterns, and follow-up training is provided to teach the patient to change these patterns in a healthy direction.<sup>3</sup>

More recently, heart rate variability has come into use as a measure of adaptability or autonomic balance. Soviet scientists were the first to study heart rate variability biofeedback, working with cosmonauts in measuring autonomic function. They found that the low-frequency (0.1-Hz) bands produced the highest frequency-specific oscillations in heart rate variability, and training typically proceeds in increasing amplitude of the low-frequency band (also called the baroreceptor band). Because diminished heart rate variability is a predictor of increased risk for cardiac mortality, teaching patients to increase heart rate variability made sense. The training involves instruction in breathing at an identified resonant frequency that is related to optimal low-frequency band power.<sup>4</sup>

### ■ LEARNING AND MODELS OF BIOFEEDBACK

Accurate feedback facilitates the learning of any skill, whether it be sinking a golf putt, solving an algebra problem, or controlling physiologic behavior. A man playing darts blindfolded is unlikely to achieve as good a score as he would with the blindfold off, because feedback makes a difference.<sup>5</sup>

Four conditions are important for effective learning;<sup>5</sup> the learner must:

- Have the capacity to respond
- Be motivated to learn
- Be positively reinforced for learning
- Be given accurate information about the results of the learning effort.

#### Direct feedback learning model

The direct feedback learning model assumes that adding feedback to the other important conditions of learning

will result in a patient gaining control of the relevant physiology being targeted. This model has been used in treating many disorders, including Raynaud phenomenon and urinary and fecal incontinence.

Biofeedback training in this model may involve a coach/instructor/therapist only to the extent of explaining the equipment and its use. In other words, the coach “teaches the patient how to use the mirror.” More commonly—particularly for training in lowered arousal for patients in whom stress reactivity is a significant factor in the development and maintenance of excessive (sympathetic nervous system) arousal that leads to symptoms—a skilled therapist is present. The therapist not only teaches the patient how to use information from biofeedback instruments but also guides the patient in identifying and changing cognitive, emotional, and behavioral patterns that contribute to excessive reactivity. The relationship of physiologic reactivity to the subject matter under discussion also helps diagnostically in identifying stressful areas of life, particularly in psychophysiologic responders who are repressive and denying and who are not good at identifying the stressors in their lives. The equipment becomes a mirror that lets the patient see a problem that he or she had not identified as such.<sup>5</sup>

#### Therapeutic/stress-management/biofeedback model

When treating patients with disordered physiology (including autonomic imbalance) in the therapeutic/stress-management/biofeedback model, it is essential to understand each patient as an individual. In this model, stress management and psychotherapeutic interventions address particular vulnerabilities that lead to excessive arousal. This approach starts with a psychophysiologic assessment in which resting levels of relevant physiologic dimensions are measured; this is followed by imposition of stressors to measure reactivity and then by a recovery period in which rate and extent of recovery are measured. An interview and psychological test help determine which cognitive, emotional and behavioral patterns contribute to vulnerability. Patients typically respond well to this approach. It is common for patients to use such descriptions as, “I break out in a cold sweat when I’m stressed,” or “I feel heartsick when I’m stressed,” which suggests that the notion of mind-body interaction resonates with patients.<sup>6</sup>

The complexity of biofeedback-assisted psychotherapeutic stress-management training is high. Content analyses of patient–therapist interactions suggest at least a dozen possible different processes operating, as detailed in **Table 1**.<sup>6</sup>

## ■ CRITERIA FOR EVALUATING EFFICACY OF BIOFEEDBACK INTERVENTIONS

Several years ago a task force of the Association for Applied Psychophysiology and Biofeedback and the Society for Neuronal Regulation published criteria for evaluating the clinical efficacy of biofeedback/psychophysiological interventions.<sup>7</sup> These criteria are detailed below.<sup>3,7</sup>

### Level 1: Not empirically supported

This designation applies to interventions supported only by anecdotal reports and/or case studies in non-peer-reviewed venues (ie, not empirically supported).

### Level 2: Possibly efficacious

This applies to interventions supported by at least one study of sufficient statistical power with well-identified outcome measures but which lacked randomized assignment to a control condition internal to the study.

### Level 3: Probably efficacious

This applies to interventions supported by multiple observational studies, clinical studies, wait-list–controlled studies, and within-subject and intrasubject replication studies that demonstrate efficacy.

### Level 4: Efficacious

- a. In a comparison with a no-treatment control group, alternative treatment group, or sham (placebo) control using randomized assignment, the intervention is shown to be statistically significantly superior to the control condition, or the intervention is equivalent to a treatment of established efficacy in a study with sufficient power to detect moderate differences, *and*
- b. The studies have been conducted with a population treated for a specific problem, for whom inclusion criteria are delineated in a reliable, operationally defined manner, *and*
- c. The study used valid and clearly specified outcome measures related to the problem being treated, *and*
- d. The data were subjected to appropriate data analysis, *and*
- e. The diagnostic and treatment variables and procedures were clearly defined in a manner that permits replication of the study by independent researchers, *and*
- f. The superiority or equivalence of the intervention has been shown in at least two independent research settings.

### Level 5: Efficacious and specific

This designation applies when the intervention has been shown to be superior to credible sham therapy,

**TABLE 1**

### Processes potentially at work during biofeedback-assisted psychotherapeutic stress management<sup>6</sup>

1. Operant conditioning, with success in changing physiology representing immediate positive reinforcement.
2. Feedback learning, with the biofeedback equipment representing imposition of an external psychophysiological feedback loop upon already existing internal feedback loops.
3. Feedback learning, with the biofeedback equipment affecting general arousal through impact on already existing feedback loops of the homeostatic adaptive control systems.
4. Learning the relaxation response via imagery and cognitive exercises.
5. Modifying assumptions, attitudes, and expectations that lead to psychophysiological stress reactions.
6. Enhancing self-awareness in general, including awareness of bodily functioning, by getting specific information about bodily functioning and experimenting with the relationship of physiologic functioning to thought patterns.
7. Resolving conflicts by discussing them with a therapist, thus reducing self-generated stressors leading to psychophysiological reactions.
8. Responding to hypnotic suggestion of greater well-being while in an altered state of consciousness induced by narrowing of attention.
9. Faith healing, with belief in the process being a curative agent leading to placebo healing.
10. Changing behavior to reduce stressors, in response to specific counseling of the therapist.
11. Experiencing an increase in self-esteem secondary to warmth, genuineness, and empathy of the therapist, thereby reducing stress.
12. Emulating a relaxed therapist who is not upset thinking about and discussing emotionally laden topics.
13. Articulating values and shifting them to enable attitudinal, behavioral, and emotional change.
14. A cathartic re-experiencing and emotional release that reduces stress.
15. Changing the locus of control so that the patient takes greater responsibility for his or her own well-being.

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pill therapy, or alternative bona fide treatment in at least two independent research settings.

### Efficacy ratings for specific disorders

In their recent text on biofeedback and neurofeedback, Yucha and Gilbert<sup>3</sup> rated the available evi-

**TABLE 2**  
**Efficacy ratings for biofeedback interventions**  
**in various medical conditions\***

**Level 5: Efficacious and specific**  
 Urinary incontinence in females<sup>8</sup>

**Level 4: Efficacious**  
 Anxiety<sup>9</sup>  
 Attention deficit disorder<sup>10</sup>  
 Headache (adult)<sup>11</sup>  
 Hypertension<sup>12</sup>  
 Temporomandibular disorders<sup>13</sup>  
 Urinary incontinence in males<sup>14</sup>

**Level 3: Probably efficacious**  
 Alcoholism/substance abuse<sup>15</sup>  
 Arthritis<sup>16</sup>  
 Chronic pain<sup>17</sup>  
 Epilepsy<sup>18</sup>  
 Fecal elimination disorders<sup>19</sup>  
 Headache (pediatric migraine)<sup>20</sup>  
 Insomnia<sup>21</sup>  
 Traumatic brain injury<sup>22</sup>  
 Vulvar vestibulitis<sup>23</sup>

\*Ratings are by Yucha and Gilbert<sup>3</sup> based on data from the cited references.

dence on the efficacy of biofeedback interventions in various diseases and conditions according to the above efficacy criteria. **Table 2** lists the disorders that met the three most stringent levels of evidence.<sup>3</sup>

**Despite high standards, biofeedback thrives**

The above criteria represent high standards. Since biofeedback training is often more like physical therapy or learning a language, double-blind protocols usually are not feasible, nor is sham training. Moreover, the effectiveness of training is perhaps even more difficult to assess in daily practice, with the inevitable multiplicity of confounding variables. Nevertheless, biofeedback training for many disorders is standing the test of both time and outcomes research, and it is increasingly embraced by the public and recognized by health care insurers and professionals alike.

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**Correspondence:** Michael G. McKee, PhD, Department of Psychiatry and Psychology, Cleveland Clinic, 9500 Euclid Avenue, P57, Cleveland, OH 44195; mckee2@ccf.org.