

Part I

General Biofeedback and Neurofeedback Forwards

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The Use of General Biofeedback in the Pursuit of Optimal Performance

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Introduction

Since the opening days of the biofeedback movement in the late 1960s and early 1970s, the biofeedback paradigm has excited visions of expanding human potential (Moss, 1999). Early biofeedback research showed human beings gaining enhanced awareness and control over visceral physiology (Miller, 1969), musculature (Basmajian, 1967), and states of consciousness (Kamiya, 1969). Barbara Brown, a founder and the first president of the Biofeedback Research Society, proclaimed that biofeedback could give to the human being a *new mind* and a *new body* (Brown, 1974). Later, she imaged this new mind as a *supermind* with expanded consciousness and unlimited potential (Brown, 1980).

Much of Barbara Brown’s work, and much of the early speculation rested on the hope that EEG biofeedback would awaken human creativity and enable human beings to reach higher states of consciousness. Using EEG biofeedback to optimize performance is discussed in later chapters. Nevertheless, general biofeedback and EEG biofeedback have been used in tandem, as complementary tools to provide human beings with enhanced awareness of their mind-body lineage, increased control over their physiology, and increased access to self-regulation strategies.

Part I of this book provides examples highlighting the use of General Biofeedback in optimal performance work, including work to enhance the performance of athletes in sport, improve the learning of students in the classroom, and intensify the creativity and performance of artists in music, the graphic arts, and other artistic arenas. Clinical application and research investigations with biofeedback have steadily grown since the 1970s. Readers seeking additional general information are

referred to the following sources: Blumenstein, Bar-Eli, and Tenenbaum (2002); Collins and McPherson (2006); Hatfield and Landers (1983); Leonards (2003a,b); Petruzzello, Landers and Salazar (1991); Sime (1985); Strack and Sime (2011); Tenenbaum, Corbett, and Kitsantas (2002); and Zaichkowsky and Fuchs (1988). Readers interested in learning more about applications of EEG and neurofeedback to sports are referred to Thompson *et al.* (2008); Hatfield, Haufler, and Spalding (2006); Hatfield and Hillman (2001); Lawton *et al.* (1998); Vernon (2005); and Wilson, Sime, and Harkness (in press for 2011).

Paradigms in Biofeedback Assisted Optimal Performance Work

Several conceptual paradigms have been utilized by biofeedback professionals in optimal performance work. Although they overlap, each highlights a dimension or direction for applying biofeedback to remove impediments to performance and elicit maximal physiological responsiveness.

The relaxation paradigm

In clinical biofeedback, cultivation of the “relaxation response” is a central model driving the majority of biofeedback applications (Benson, 1975). In general, autonomic nervous system vigilance and tense and braced musculature are not conducive to optimal functioning in sports (see Zaichkowsky and Fuchs, 1988, for a review), music, and stage performance. Biofeedback assisted relaxation therapy can counteract many of the negative effects of stress in performance. In addition, biofeedback-assisted relaxation can affect functional measures reflective of athletic performance. Caird, McKenzie, and Sleivert (1999), for example, utilized multi-modal biofeedback (heart rate and respiratory measures) to augment relaxation training in long-distance runners, and showed improvements in running economy, peak oxygen consumption, and peak running velocity. Similarly Wilson and Bird (1981) compared relaxation and muscle biofeedback for flexibility to a control condition, and showed that both relaxation and biofeedback produced improved hip flexion in gymnasts.

Alleviating dysponesis

Many performing artists and athletes develop neuromuscular pain problems, some of them recurrent and eventually chronic, due to kinesiology inefficient postures and tension patterns during performance. The Whatmore and Kohli (1968, 1974) concept of *dysponesis* (misplaced effort or maladaptive tensing of the musculature) highlights the essence of this problem: Organisms suffer from misdirected effort. The nineteenth century Shakespearean actor F.M. Alexander studied his chronic vocal problems, and identified destructive postural patterns constricting the vocal

chords. His self-care evolved into the Alexander Technique, in which therapists study postural misalignment as the source of a variety of symptoms (Moss and Shane, 1999). A current example of alleviating dysponesis with biofeedback is seen in Riley (2011), who identified maladaptive postures and alignment in pianists, measurable with surface electromyography (SEMG); these patterns produce high levels of muscle tension, fatigue, discomfort, and pain. There is a musical performance deficit as well, when muscles suffer repetitive strain. Riley uses SEMG biofeedback and video feedback to retrain posture at the keyboard.

Moderating anxious cognitive processes

Ruminative and anxious thinking frequently hinders optimal responsiveness on the athletic field. Vietta Wilson has utilized EEG training to combat “busy brain,” training athletes to respond instinctively and without nonproductive thought processes (Wilson, Peper, and Moss, 2006; Wilson, Sime, and Harkness, in press). Also, Lagos *et al.* (2008) have utilized heart rate variability biofeedback to reduce anxious thoughts as a means to improve golf performance in a single case.

Resolving psychological distress that undermines optimal performance

Physiological tension is often an accompaniment of lingering psychological conflicts, traumatic experiences, and conflicts. Biofeedback can be paired with psychologically oriented therapies to more effectively resolve the psychological problems. Leddick (2011) reported on an integrative approach combining neurofeedback with psychoanalytic psychotherapy in the treatment of an under-achieving musician. Wilson and Peper (2011) combine a number of biofeedback and neurofeedback modalities with a cognitive approach to resolving serious anger episodes in a teen tennis player. The biofeedback training seems to facilitate the psychological resolution and vice versa.

Enhancing optimal physiological responsiveness

Relaxation is not the answer to every competitive problem. Rather, the capacity to relax away maladaptive tensions, while exerting with an optimal level of intensity in critical moments, provides a more comprehensive approach (Taylor, 1996). Skill training is critical in sports and performing arts, and the performer needs to develop an instinctive recruitment of skills in response to ever-changing demands in the moment. Prior to successful performance there is a deceleration in heart rate (HRD) and this corresponds to faster reaction and accompanies a process of orientation and readiness. Researchers such as Hatfield, Landers, and Ray (1984); Landers *et al.* (1980); and Wang (1987); and Landers, Boutcher, and Wang (1986) confirmed this was the case in sport performance, mainly with shooters. Carlstedt (2001)

utilized ambulatory monitoring, and showed that HRD was evident prior to action phases in tennis. In his sample, the competitors with greater HRD won the matches.

Reducing reaction time

The outcomes of many track and field events are determined by how quickly the participant can get off the blocks. Reaction time training involves focusing interventions on reducing that initial reaction time. Vietta Wilson (2001) used reaction time training from the blocks for sprinters prior to the 1988 Olympics. Pierre Beauchamp and colleagues applied reaction time biofeedback to training Canadian speed skaters in preparations for the Vancouver 2010 Winter Olympics (Harvey *et al.*, 2011). The authors emphasized reaction time as one factor, in conjunction with pre-start routine, start technique, start power and acceleration, and start confidence, in preparing the skaters for Olympic gold.

The Field of Optimal Performance Psychophysiology

Optimal performance psychophysiology: Defined

The related fields of optimal performance psychophysiology, sports psychophysiology, and performing arts psychophysiology all seek to apply the tools of stress management, muscle kinesiology, biofeedback, and neurofeedback, to remediate performance related disorders and to optimize performance. The approach of psychophysiology emphasizes the indivisibility of mind and body, and the value of integrating behavioral, mental, and physiological tools for performance focused interventions. The ultimate question framing this field is: How can we utilize psychophysiological tools and approaches to enable human beings to reach their highest level of performance and functioning.

Applications of optimal performance psychophysiology

Optimal Performance Psychophysiology has obvious value for elite performers on the stage and the athletic field, as well as for the teen athlete, the athlete in training, and musicians and stage performers at all levels of expertise. Further, there is also value in transferring the optimal performance paradigm to clinical treatment and other sectors of life. There are instances in clinical treatment where an over-focus on alleviating pathology or problems produces a diminished concept of the human being, and self-limits the possible results. Although this will not be the emphasis of this section of the book, it is useful to pose to clinical patients or business executives the optimal performance question: How can we organize your energy and our interventions to help you become everything that you are capable of becoming?

A Brief History

The history of psychophysiological approaches to sports performance pre-dates the era of modern biofeedback. Coleman Roberts Griffith, who is regarded as the “father of sports psychology,” began scientific study of the effects of psychological factors on athletics in 1918, and highlighted the place of psychomotor skills, and the measurement of reaction time (Kroll and Lewis, 2007). He demonstrated the importance of utilizing a laboratory for research in athletics (Griffith, 1930). Many of the basic scientific principles now utilized in sport psychophysiology also predate the biofeedback movement. The neurophysiology of the musculature was outlined first by Edmund Jacobson (1938) and later by John Basmajian (1967). The relationship between heart rate deceleration and performance was outlined by Lacey and Lacey (1974) and Porges (1972). Although research was being completed in biofeedback and sport since the early 1970s, the birth of sport psychophysiology as a self-conscious movement, goes back only three decades, to a breakthrough paper by Zaichowsky and Sime (1982), which advocated the application of stress management concepts in the newly defined field of sport psychophysiology.

Since 1982, several individuals have actively strived to move the field of optimal performance psychophysiology forward: Wesley Sime (2003), Vietta Wilson and Erik Peper (Wilson and Peper, 2011), Marcie Zinn (Zinn and Zinn, 2003), Len Zaichowsky (Zaichowsky and Fuchs, 1988), Gershon Tenenbaum (Tenenbaum, Corbett, and Kitsantas, 2002), and Rae Tattenbaum (Tattenbaum and Moss, 2011).

Biofeedback Tools for Optimal Performance: Modalities

Biofeedback applications to optimal performance have utilized surface electromyography (SEMG), and electroencephalography (EEG) extensively, and temperature, heart rate, heart rate variability, electrodermal measures, and respiration to a lesser extent. We turn now to a discussion of these modalities, with the exception of EEG, which is discussed elsewhere in this book.

Surface electromyography

Early work in the use of general biofeedback for optimal performance relied heavily on the surface electromyograph (SEMG), and this measure of muscle tension patterns has continued to be useful, especially in overcoming maladaptive muscle habits that inhibit more effective performance, and which lead to the many pain syndromes plaguing athletes and performance artists. George Whatmore and Daniel Kohli (1974), mentioned earlier for advancing the concept of dysponesis, used eight channels of SEMG monitoring to identify specific destructive muscle habits. Later this concept of muscular dysponesis was applied by a variety of individuals within

the biofeedback movement, to identify self-defeating muscle habits affecting both athletes and performing artists. Early leaders in this direction were Wilson and Bird (1981) and Cummings, Wilson and Bird (1984), who used the SEMG to reduce muscle tension in the hamstring of gymnasts and increase their flexibility, and to improve flexibility in sprinters.

Electrodermal activity

The electrodermograph (EDR) imposes an imperceptible current across the skin and measures how easily it travels through the skin. When anxiety raises the level of sweat in a sweat duct, conductance increases (Shaffer and Moss, 2006). The EDR is a useful biofeedback tool for cognitive quieting and emotional regulation. Ideally, athletes will shift spontaneously and flexibly between cognitively quiet states and maximal arousal and attunement. EDR is useful in training the self-quieting. Wilson, Sime, and Harkness (in press) show that EDR is useful in desensitizing the disruptive emotions reactive to past failures, falls, injury, and the like, allowing the athlete to enter practice and competition with a calmer more optimal emotional state.

Temperature

Peripheral skin temperature is a useful tool in psychophysiological assessment and in relaxation training. Skin temperature mainly reflects arteriole diameter. Hand-warming and hand-cooling are produced by separate mechanisms and their regulation involves different skills. Increased sympathetic activation associated with anxiety and hypervigilance can produce vasoconstriction and hand-cooling. In athletics, the psychophysiologicalist must become familiar with what is optimal and normal for various sport events and in each stage in a competition (Wilson, Sime, and Harkness, in press). Wilson reports that elite endurance athletes such as skaters and marathon runners show cooler peripheral temperatures in nonstressful times, which is probably an adaptive response to the demands of the event.

More frequently in biofeedback practice, even with athletes, cool hands are interpreted as a sign of a stress response, and hand-warming is used as a tool to facilitate relaxation. Thermal biofeedback has been shown in one study to be effective in facilitating improved performance in cold weather sports, such as hockey and curling (Kappes and Chapman, 1984). This may be important to the athlete's dexterity in manipulating equipment in outdoor sports. Harkness (2009) reported using hand-warming training with an Olympic shooting gold medalist, but with mixed results. One positive advantage of thermal training is that athletes and stage performers can learn to self-monitor skin temperature as one index for performance related stress, and can also utilize hand-warming and imagery for effective self-relaxation.

Respiratory biofeedback

Breath control is critical in athletics for optimal performance and for its autonomic regulatory effects. Anxiety and stress-oriented thinking disrupts the breath pattern, and undermines the chemistry surrounding the respiratory cycle, including carbon dioxide levels and the body's acid base balance. One study used breath training without biofeedback, and showed that paced slowed breathing dramatically reduced arterial hypertension during heavy, dynamic weightlifting, thereby reducing health risk to the athletes (Narloch and Brandstater, 1995). Respiratory biofeedback is a useful assessment tool, and a useful tool for retraining effortless, relaxed diaphragmatic breathing and autonomic regulation. Respiration is also a component within heart rate variability training, which will be discussed below.

Emerging trends: Cardiovascular measures

At present, heart rate (HR) and heart rate variability (HRV) are gaining ground both as indices of autonomic dysregulation, and as tools for relaxation and autonomic regulation. Lopes and White (2006) reviewed the significance of heart rate and heart rate variability (HRV) for athletics. Aerobically fit young athletes tend to exhibit lower resting heart rates, and greater heart rate variability (more prominent respiratory sinus arrhythmia, or heart rate oscillations in phase with the breath cycle) than non-athletes. Research studies (Porges, 2007; Thayer and Lane, 2009) also show that heart rate variability is associated with improved physiological, emotional and cognitive performance, which is believed to be due to the increased communication between the heart and brain. Athletes have been shown to have higher levels of HRV when compared to non-athletes, which is attributed to increased parasympathetic activity (Puig *et al.*, 1993).

Heart rate variability biofeedback training increases variability further with a variety of effects reported. Heart rate variability biofeedback has been reported to improve reaction time and relaxation in wrestlers (Vaschillo, Visochin, and Rishe, 1999) and batting performance in baseball by 60% (Strack, 2003). Heart rate variability was also found to be a viable and convenient measure of arousal in pre-competitive situations for golfers (Murray and Raedeke, 2008). Bruno de Michelis, the trainer for the AC Milan soccer group, utilizes a specific respiration training pattern along with HRV training, to create maximal heart rate oscillations, with enhanced athletic resilience (Wilson, Peper, and Moss, 2006). One study (Tanis, 2008), however, found no improvements in performance for female volleyball players who trained with heart rate variability biofeedback.

Heart rate variability has also been utilized for calming and optimal autonomic balance. In 2008, Lagos *et al.* (2008) published a case study describing the use of heart rate variability biofeedback with a teen golfer, alleviating his performance anxiety and improving his competitive play. Later Lagos *et al.* (2011) provided a follow-up study, integrating heart rate variability biofeedback with virtual reality training to enhance golf performance.

Standards for Application

The field of sport psychophysiology and performance psychophysiology is not yet standardized, and few guidelines exist for consistency in intervention protocols or for research. The field is still at a stage where much of the useful work is reported in case studies, in part because the sport psychophysiology is almost always responsible to the athletic coach or trainer, and the competitive performance priorities win out over research.

Professional Resources

Organizations

The field of general biofeedback is represented by a professional society in North America, the Association for Applied Psychophysiology and Biofeedback (AAPB), which supports three professional publications, holds an annual meeting, and supports webinars and other workshops. The European equivalent for AAPB is the Biofeedback Foundation of Europe. In addition, there is a certification organization, the Biofeedback Certification International Alliance, which establishes a standard for knowledge and skills for the field, and provides certification programs in general biofeedback, neurofeedback, and pelvic floor biofeedback. A third organization, the International Society for Neurofeedback and Research, focuses on neurofeedback (EEG biofeedback), but includes some programs in general biofeedback in its conferences.

Division 47 of the American Psychological Association is dedicated to sport, exercise, and performance psychology, with little emphasis on psychophysiology. Nevertheless, for those individuals in the field who are psychologists, Division 47 offers a journal and newsletter, and a link to the organized resources of the American Psychological Association.

Journals

The scholarly journal published by AAPB is called *Applied Psychophysiology and Biofeedback* (formerly *Biofeedback and Self-Regulation*). Over the past 35 volumes, APB has published many articles on optimal performance, such as: (a) the Wilson and Bird (1981) early report on two studies applying biofeedback assisted muscle relaxation training or relaxation alone first to 10 male gymnasts and then to 15 female gymnasts; with evidence in the first study showing relaxation in both groups enhanced hip flexion; (b) the Morasky, Reynolds, and Sowell (1983) study that provided clarinet players with SEMG training, and showed reduction in muscle tension while musical performance measures remained at or above baseline levels, (c) the Bolliet, Collet, and

Dittmar (2005) report on the measurement of six autonomic variables, (d) the Raymond, Sajid, Parkinson, and Gruzelier (2005) study that compared neurofeedback, heart rate variability training, and a control conditions in ballroom and Latin dancers, and found performance benefits for both biofeedback groups, and not in controls, and Vernon's (2005) critical review of the evidence for neurofeedback applications to optimal performance.

AAPB also sponsors a second publication, *Biofeedback*, which has published three special issues on optimal performance, and a number of individual reports on optimal performance work in sports, music, and other performing arts. In 2002, *Biofeedback* published a special issue, entitled "Performing Arts Psychophysiology through the Lifespan." The issue was edited by Donald Moss and Marcie Zinn, and included a broad range of applications of general biofeedback to the performing arts, including an overview of the use of psychophysiological approaches to the performing arts (Zinn and Moss, 2002), an article by John Gruzelier (2002) on his groundbreaking applications of EEG biofeedback to music performance, a case report on applying "constraint induced movement therapy for focal hand dystonia in musicians" (Candia *et al.*, 2002), and an annotated bibliography of publications on psychophysiological interventions for the performing arts, by Marcie Zinn (2002).

In 2003, Jeffrey Leonards provided a comprehensive review, in two articles, of the progress in the application of biofeedback with athletes, and highlighted the burgeoning field of sport psychophysiology as an applied science in its own right, with a growing evidence base.

In 2006, the Italian soccer team utilized a panoply of general biofeedback and EEG biofeedback tools on their way to the World Cup. Vietta Wilson, Erik Peper and Donald Moss (2006) then published in *Biofeedback* a broad review of the use of biofeedback and neurofeedback in sports. The article examined those biofeedback techniques known to be used in the so-called "Mind-Room" for the Italian soccer team, and highlighted four components widely used in sports psychophysiology: the training of optimal pre-performance states, the multi-modality assessment and training of optimal physiological functioning, the desensitization of anxious or otherwise maladaptive responses, and the inhibition of disruptive inner self-talk and negative self-focus. In 2009, Timothy Harkness also reported on his use of biofeedback to coach India's first gold medalist competitive shooter.

In Spring 2011, *Biofeedback* published an additional special issue, under the leadership of guest editor Rae Tattenbaum, highlighting a broad range of articles documenting the maturing of optimal performance biofeedback and neurofeedback work. A further special issue on optimal performance will appear in Fall 2011, and will feature reports on international applications of the psychophysiological paradigm to optimal performance.

Those interested in the field may also benefit from access to the journals *Sport, Exercise, and Performance Psychology*, *Journal of Sport Psychology*, and *Journal of Clinical Sport Psychology*.

Conclusion

Optimal potential has been a dream and an objective within the biofeedback movement from the beginning. Optimal performance work now guides athletes to more competitive performance, enhances the performance of dancers and musicians, and awakens the creativity and focus of artists alike. Optimal performance work also provides the tools to alleviate the injuries that so often accompany repetitive strain and motion in both the arts and sport. Most of the modalities of general biofeedback have been used to some advantage in optimal performance work: surface electromyography, electrodermal biofeedback, thermal biofeedback, respiratory training, and heart rate and heart rate variability biofeedback. The tools of general biofeedback are used alone, or in conjunction with electroencephalography. The body has a head, and the effects of peripheral and central interventions are complementary and often augment one another. The chapters in this section provide an excellent view of the field as it is evolving today.

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