CHAPTER 1

The History and Definitions of Biofeedback and Applied Psychophysiology

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This chapter conveys the converging trends that influenced the development and journey of applied biofeedback, and the broader field of applied psychophysiology.[1] This historical perspective is designed to help the reader understand the origins of the multifaceted and multimodality field of biofeedback, including a history of specialty modalities and applications (e.g., electroencephalographic [EEG] biofeedback, a.k.a. neurofeedback). It also seeks to help illuminate the broader concept of applied psychophysiology, and to give perspective to the name changes of the primary professional membership organization and its journal.

Applied biofeedback began in the United States with the convergence of many disciplines in the late 1950s. The major antecedents and fields from which it developed include the following. (*Italics* on the first use of a term indicate that the term is included in the Glossary.)

1. *Instrumental conditioning* of *autonomic nervous system* (ANS) responses
2. Psychophysiology
3. Behavior therapy and behavioral medicine
4. Stress research and stress management strategies
5. Biomedical engineering
6. Surface electromyography (EMG), diagnostic EMG, and control of *single motor units*
7. Consciousness, altered states of consciousness, and electroencephalography (EEG biofeedback also known as neurofeedback)
8. Cybernetics
9. Cultural factors.
10. Professional developments[2]
11. Definitions

The order of the items in this list reflects neither historical sequence nor relative importance. Other historical perspectives on biofeedback may be found in Basmajian (1989), Shaffer (2010), and Peper and Shaffer (2010). (See *www.marksschwartzphd.com* for other references and links to selected historical perspectives.)

INSTRUMENTAL CONDITIONING OF ANS RESPONSES

Learning theory developed within experimental psychology. Reinforcement is necessary for operant conditioning or instrumental conditioning to occur. From this perspective, both overt behaviors and covert behaviors, such as thoughts, feelings, and physiological responses, are functions of the antecedents and consequences of such behaviors. This model describes the learning of responses instrumental to obtaining positive or avoiding negative consequences.

The prevailing scientific viewpoint for several decades has been that only the voluntary musculoskeletal system, mediated by the *central nervous system* (*CNS*), is responsive to *operant conditioning*. The older view held that the ANS functioned automatically beyond conscious awareness, and hence beyond voluntary control. Most scientists thought that the internal, homeostatic controls for functions such as circulation and digestion were innate and unaffected by self-regulatory learning. Most scientists assumed that ANS functioning or *visceral learning* was modifiable only via *classical conditioning*, if subject to learning at all. In this view, responses are automatic after conditioning occurs. In classical conditioning, thoughts can even become conditioned stimuli (CSs) and elicit physiological responses.

The strong biases against instrumental conditioning of the ANS and the visceral responses it controls limited the amount of experimental work in this area until a few decades ago (Miller, 1978). Studies with humans and animals showed that instrumental training could produce increases and decreases in bodily responses (see early reviews by Harris & Brady, 1974; and Kimmel, 1979, and Taub, 2010).

Research indicated that individuals could gain volitional control over several different ANS functions without learning that could be attributed to cognitive factors. Many scientists and professionals were very skeptical of these findings. There was much disagreement concerning whether the research really demonstrated cortical control over ANS activity. As research advanced, it became clear that to show operant learning effects in the ANS, researchers needed more sophisticated designs. They had to rule out *skeletally mediated mechanical artifacts* and *visceral reflexes*.

The best organized and most articulate history of the very challenging research on instrumental conditioning of autonomic response systems, and in particular the brilliance of Neal Miller, was provided by Ed Taub (2010). Every student of the history of biofeedback, the history of psychology, and indeed research methods, should read this presentation by Taub. (With permission, the entire article is reproduced at *www.marksschwartzphd.com* for readers who are interested.)

- Eliminating or ruling out somatic mediation of the autonomic responses was the problem to be resolved.
- Studies of heart rate changes with chemically paralyzing and artificially respirated rats, thus without somatic mediation, were reported (Miller & DiCara, 1967; DiCara & Miller 1968a, 1968b, 1968c, 1968d).
- Instrumental condtioning of autonomic functioning was controversial among psychophysiological researchers.
- Several attempts by other researchers and by Miller and his students to replicate these studies were unsuccessful. Most researchers who were familiar with this research attributed the DiCara and Miller (1967a) results to an anomaly despite other, similar and reliable, albeit smaller, results by other investigators (Trowill, 1967; Hothersall & Brener, 1969; Slaughter et al., 1970).
- Miller and his students made extensive and meticulous efforts to reproduce the studies and although unsuccessful, the process provided an outstanding example of the Strong Inference (Dworkin & Miller, 1986; Taub, 2010) research model. They evaluated a large number of alternative hypotheses.
- Adverse publicity about the unsuccessful replications created a strong negative association.
- Taub (2010) pointed out the terrifying limitations of any attempted learning research with paralyzed rats or any vertebrate.
- The second experimental question regarding biofeedback instrumental conditioning of any ANS response without somatic mediation was reported by Miller and Brucker (1979) with patients with quadriplegia, thus without sufficient somatic muscle activity mediating the strong increase in blood pressure enough to manage the low blood pressure (i.e., orthostatic) due to the patients typical reclining position. Miller and Brucker noted that the results were "strongly indicating that these patients can learn unusually large increases in blood pressure and that this visceral response can be performed independently of skeletal responses" (Taub, 2010, p. 113).
- Taub's thermal biofeedback studies (Slattery & Taub, 1976; Taub & School, 1978) extended the research regarding instrumental conditioning of ANS without somatic mediation. Temperature biofeedback from varied and specific locations on a hand resulted in "very clear anatomical differentiation of the temperature response" and "a large response around the feedback locus, and much less or none at other locations" (Taub, 2010, p. 113).
- Taub (2010) reported his research with 11 participants attempting to alter skin temperature

> up or down on one digit compared to another. He reported that for eight subjects, there was "significantly greater temperature response on the designated digit than at the other one" (Taub, 2010, p. 114). With other controls, they concluded that "the anatomical specificity results represented differential alterations in blood flow and were not due to an artifact . . . [and] in particular, not to somatic mediation involving muscle activity changes from any of the locations . . . recorded" (Taub, 2010, p. 114).

The research with instrumental conditioning of visceral responses mediated by the ANS provided a major impetus to the development of clinical biofeedback. It appeared to resolve the controversy over whether such conditioning was a legitimate phenomenon. An assumption of clinical biofeedback is that it can help persons improve the accuracy of their perceptions of their visceral events. These perceptions allow them to gain greater self-regulation of these processes.

This operant model of biofeedback has significant heuristic value. One can apply principles of instrumental conditioning to physiological self-regulation.

Although it is helpful to view biofeedback primarily as instrumental conditioning of visceral responses, this model is limiting in that some professionals believe that human learning includes major cognitive dimensions, as well as environmental reinforcers, for example, thinking, expectation, visualization and imagery, foresight and planning, and problem-solving strategies.

One can include cognitive factors within the operant conditioning model. However, professionals adhering to more stringent interpretations of the model consider cognitive factors inadmissible, because one cannot observe or objectively measure them. Nevertheless, studies of motor skill learning (Blumenthal, 1977) show that humans develop mental models ("motor programs") of what a skilled movement should be like. Furthermore, research shows that one may acquire behavior without obvious practice or even reinforcement. This evidence comes from latent learning experiments (Harlow & Harlow, 1962), studies of discovery learning (Bruner, 1966), and studies of *observational learning* involving imitation of a model (Rosenthal & Zimmerman, 1978).

Increased acceptance for the role of mental processes in learning led to cognitive-behavioral therapies and studies of cognitively mediated strategies in the changes occurring during biofeedback therapies. The emphasis on cognitive learning also supported the applications of *cybernetics* to biofeedback.

PSYCHOPHYSIOLOGY

David Shapiro offered the first academic course in *psychophysiology* at Harvard University in 1965. The *Handbook of Psychophysiology*, a major publication, appeared 7 years later (Greenfield & Sternback, 1972).

Psychophysiology involves the scientific study of the interrelationships of physiological and cognitive processes. Some consider it a special branch of physiology. Others also consider it an offspring of psychobiology, which in turn is the child of the marriage between the physical and social sciences (Hassett, 1978). Physiological psychologists often manipulate physiology and observe behavior. In contrast, psychophysiologists often facilitate, manage, guide, hinder, or obstruct human psychological variables and observe the physiological effects.

As a form of "applied psychophysiology,"[3] clinical biofeedback helps people alter their behaviors with feedback from their physiology. Some providers of clinical biofeedback used to refer to themselves as "clinical psychophysiologists."

BEHAVIOR THERAPY AND BEHAVIORAL MEDICINE

The fields of behavior therapy and behavioral medicine are related outgrowths of both learning theory and psychophysiology. "Behavior therapy" developed in the 1950s as an alternative to *insight-oriented psychodynamic theories and therapies* for mental disorders. The roots of behavior therapy include the notion that one learns maladaptive behaviors; therefore, in most cases, one can unlearn them. The model is largely educational rather than medical. It applies the principles of operant and respondent conditioning, as well as of cognitive learning, to change a wide range of behaviors. Many professionals view some biofeedback applications as a form of operant learning. Others view biofeedback more cognitively within an information-processing model.

"Behavioral medicine" is another outgrowth of learning theory, psychophysiology, and behavior therapy. This specialty developed within behavior therapy and psychosomatic medicine. It appeared as a distinct entity in the late 1970s. Behavioral medicine focuses on applications of learning theories to medical disorders and other health-related topics. It does not focus on psychopathology or mental disorders. G. E. Schwartz and Weiss (1978) reported a definition of behavioral medicine proposed at the Yale Conference held in 1977:

> Behavior medicine is the field concerned with the development of behavior science knowledge and techniques relevant to the understanding of physical health and illness and the application of this knowledge and these techniques to diagnosis, prevention, treatment, and rehabilitation. Psychosis, neurosis, and substance abuse are included only insofar as they contribute to physical disorders as an end point. (p. 379)

Behavioral medicine also developed because traditional medical approaches were insufficient for managing and treating many chronic diseases, conditions, and health-damaging or maladaptive behaviors. This new specialty goes beyond the traditional germ theory of the etiology and progression of diseases. It recognizes the important roles of stress, lifestyle, habits, and environmental variables in the development, maintenance, and treatment of medical and dental diseases and conditions.[4]

Behavioral medicine places much emphasis on the patient's role in prevention of and recovery from organic diseases and conditions. The same emphases are clear in applied or clinical biofeedback. In fact, some professionals consider clinical biofeedback to be a major specialty within the broader field of behavioral medicine (Birk, 1973; Olton & Noonberg, 1980).

The contributions of behavior therapy and behavioral medicine to the development and applications of applied biofeedback and applied psychophysiology are clear. The interactions among professionals from all of these fields will continue to be enriching.

STRESS RESEARCH, RELAXATION THERAPIES, AND OTHER STRESS MANAGEMENT TECHNIQUES

An important area of behavioral medicine is research on the effects of stress on causing physical symptoms and altering the immune system. However, research on stress began long before the development of behavioral medicine or biofeedback; in fact, both fields have their roots partly in stress research. One has only to remember Hans Selye's (1974) report of more than 130,000 entries on stress that showed the extent of this already immense body of research.

Pioneering research was conducted by the physicians Claude Bernard and Walter B. Cannon, as well as by Selye. Pi Suñer (1955) observed that Bernard developed the concepts of physiological "homeostasis" as the major process by which the body maintains itself. As Langley (1965) noted, the concept became integral to the discipline of physiology. Physical and mental disease are thought to occur because some homeostatic feedback mechanism is malfunctioning. One of the major effects of such homeostatic imbalance is stress.

In his book *The Wisdom of the Body*, Cannon (1932) indicated the natural causes and results of the innate stress response. He named this response *fight or flight*. Selye's (1974, 1976, 1983) extensive research led to a triphasic conceptualization of the nature of the physiological stress response: the stages of alarm, resistance, and exhaustion.

The brilliant and pioneering work of Cannon and Selye contributed significantly to the development of the field of psychosomatic medicine. Their work increased awareness of the role of stress in physical and mental diseases. This awareness nurtured applied biofeedback, and many of these applications focused on stress-related disorders. Furthermore, as noted by Miller (1978), the emphasis of biofeedback on measuring and producing changes in bodily processes contributes to other behavioral techniques for relieving stress effects.

Many stress management systems evolved with the awareness of the effects of stress on health and disease. Included among these are many relaxation therapies, and some observers perceive biofeedback as a specific treatment modality within this group. In practice, the effects of relaxation have a major role in achieving the therapeutic effects with some forms of biofeedback. A very early form of physical relaxation is "hatha yoga," adopted from the Far East and popularized in Western countries in the 1960s. In the United States in the 1930s, Edmund Jacobson (1938, 1978) developed "progressive relaxation" (PR), sometimes also called "progressive muscle relaxation," which consists of a series of muscle activities designed to teach people ways to distinguish degrees of tension and relaxation, and to reduce specific and general muscle tension. It also helps reduce or stop many symptoms and some causes and adverse effects of stress. McGuigan and Lehrer (2007), as two of Jacobson's students and ardent authorities, discussed the history and techniques from their unique perspective. Lichstein (1988) provided one of the most thorough detailed texts on relaxation strategies and research results. Other very useful resources are the books by Smith (1989, 1990, 2001, 2005; also see Chapter 12 in this volume). Modifications of progressive relaxation have been developed by Wolpe (1973), Bernstein and Borkovec (1973), Bernstein, Carlson, and Schmidt (2007), and Jacobson and McGuigan (1982). A related technique developed in England by Mitchell (1977, 1987) involves stretch–release procedures. In addition to the physiological relaxation procedures, there has been a proliferation of primarily mental techniques, most of which involve some form of meditation. Islamic Sufis, Hindu yogis, Christian contemplatives, and Hasidic Jews have practiced religious meditation for centuries.

Meditation became popularized in the United States in the 1960s as a result of the development of Transcendental Meditation (TM), practiced and promoted by a teacher from India named Maharishi Mahesh Yogi (Forem, 1974). More Westernized variations of TM were subsequently developed as "clinically standardized meditation" (Carrington, 1977, 1978, 1998, 2007) and the "relaxation response" (Benson, 1975). Stroebel's (1982) "quieting reflex" is a modification of a meditation technique combined with physiological relaxation.

Another meditation approach is "open focus," developed by Fehmi and Fritz (1980), which has recently experiencined a contemporary updating (Fehmi & Robbins, 2009). It is closer to Soto Zen meditation in its goal of seeking a content-free and quiet mind, by contrast with the focused concentration of yoga and TM. The emigration of Zen Buddhist teachers to the United States beginning in the 1940s was yet another factor contributing to the meditation movement. See Carrington (2007) and Kristeller (2007) for more history of modern forms of mantra meditation and for mindfulness meditation, respectively.

There are still other approaches involving relaxation/meditation: Ira Progoff's (1980) "process meditation," José Silva's (1977) "Silva mind control," and C. Norman Shealy's (1977) "biogenics." Practitioners often combine relaxation/meditation techniques with biofeedback instrumentation to enhance the learning of psychophysiological self-regulation.

Hypnosis is yet another approach developed to help persons to control pain and stress. Hypnosis developed slowly from the 1700s until the 20th century. Over the past few decades it has become more sophisticated and empirically grounded as a set of therapeutic techniques. Liebeault, Charcot, and Freud were among the first to apply the techniques to patients (Moss, 1965). Twentieth-century researchers, such as Hull, Barber, Hilgard, Weitzenhoffer, and Erickson, conducted rigorous investigations into the parameters of hypnosis. Some, like Wickramasekera (1976, 1988), reported integrations of hypnosis and biofeedback.

In Germany, early in the 20th century, J. H. Schultz developed a form of physiologically directed, self-generated therapy called "autogenic training" or "autogenic therapy." Wolfgang Luthe (1969) brought it to North America and reported extensive research and therapeutic applications of this technique, variations of which are now also in common practice.

BIOMEDICAL ENGINEERING

Without high-quality instrumentation for measuring physiological events accurately and reliably, there would be no biofeedback. As Tarlar-Benlolo (1978) reminds us, "prior to World War II, available equipment was not sufficiently sensitive for measuring most of the body's internally generated electrical impulses" (p. 728). Progress occurred after the war.

Biomedical engineers have developed technology that is both noninvasive and very sophisticated. Surface recordings used for biofeedback measurement provide feedback for many different physiological activities. Feedback can also be provided for angles of limbs and the force of muscles and limbs. Instruments continuously monitor, amplify, and transform electronic and *electromechanical* signals into audio and visual feedback—understandable information.

Now multiple and simultaneous recordings of several channels of physiological information are available with instrumentation linked to computers. Computers allow great storage capabilities, rapid signal processing and statistical analyses, simultaneous recording and integration of multiple channels, and displays that only a few years ago were impossible.

EMG, DIAGNOSTIC EMG, AND SINGLE-MOTOR-UNIT CONTROL

The workhorse of the biofeedback field has long been surface *electromyography* (abbreviated here as EMG, though SEMG is also used). According to

Basmajian (1983), EMG instrumentation grew out of the studies of neuromuscular and spinal cord functions. He reminds us that "it began with the classic paper in 1929 by Adrian and Bronk, who showed that the electrical responses in individual muscles provided an accurate reflection of the actual functional activity of the muscles" (p. 2).

Physicians have used EMG for diagnosing neuromuscular disorders for many decades. As early as 1934, reports indicated that voluntary, conscious control over the EMG potential of *single motor units* was possible (Smith, 1934). Marinacci and Horande (1960) added case reports of the potential value of displaying EMG signals to assist patients in neuromuscular reeducation. Basmajian (1963, 1978) also reported on the successful control of single motor units.

Several investigators reported EMG feedback in the rehabilitation of patients after stroke (Andrews, 1964; Binder-MacLeod, 1983; Brudny, 1982; Basmajian, Kukulka, Narayan, & Takebe, 1975; Wolf & Binder-MacLeod, 1983). Such research was important in the development of applied biofeedback, especially for the field of neuromuscular rehabilitation. Thus, EMG biofeedback gained solid support among researchers and clinicians.

Practitioners have also used EMG feedback for treating symptoms and disorders such as tension headaches and tension myalgias, temporomandibular disorders, pelvic floor disorders that include incontinence, and many other conditions (see Part VI, this volume).

CONSCIOUSNESS, ALTERED STATES OF CONSCIOUSNESS, AND EEG FEEDBACK

Humanistic psychology reestablished the human self as a legitimate source of inquiry, and scientists in transpersonal psychology and neurophysiology renewed the study of human consciousness. Theorists such as Tart (1969), Krippner (1972), Ornstein (1972), Pelletier and Garfield (1976), G. E. Schwartz and Beatty (1977), and Jacobson (1982) are among those who have made significant contributions to our understanding of human consciousness.

Many studies of altered states of consciousness induced by drugs, hypnosis, or meditation have added to our knowledge of the relationships between brain functioning and human behavior. Such research helped stimulate the use of *electroencephalography* (*EEG*) in biofeedback, which also focuses on the functional relationships between brain and behavior.

In the early 1960s, studies began appearing on the relationships between EEG *alpha wave activity* (8–12 hertz [Hz]) on the one hand, and emotional states and certain states of consciousness on the other. Alpha biofeedback, commonly reported as associated with a relaxed but alert state, received its most attention in the late 1960s. Clinical applications were mostly for general relaxation.

Kamiya (1969) reported that one could voluntarily control alpha waves—previously believed impossible Support came from Brown (1977), Nowlis and Kamiya (1970), and Hart (1968). "Though these studies tended to lack systematic controls, they nonetheless caught the imagination of many serious scientists as well as the media" (Orne, 1979, p. 493). Some investigators and practitioners continued to advocate the value of alpha biofeedback through the early 1980s (e.g., see Gaarder & Montgomery, 1981, for a discussion), despite recognizing that "there was no clear-cut and concrete rationale to explain why it should help patients" (p. 155). In contrast, Basmajian (1983) noted that "alpha feedback . . . has virtually dried up as a scientifically defensible clinical tool. . . . It has . . . returned to the research laboratory from which it probably should not have emerged prematurely. Through the next generation of scientific investigation, it may return as a useful applied technique" (p. 3).

Other investigators studied specialized learning processes and other EEG parameters, such as theta waves, evoked cortical responses, and EEG phase synchrony of multiple areas of the cortex (Beatty, Greenberg, Deibler, & O'Hanlon, 1974). Selected brain areas and EEG parameters (e.g., *sensorimotor rhythm* and *slow-wave activity*) became the focus of well-controlled studies. These emerged as effective therapeutic approaches for carefully selected patients with CNS disorders such as epilepsy (Lubar, 1982, 1983; Sterman, 1982; see Strehl, Chapter 37, this volume), as well as for some patients with attention-deficit/hyperactivity disorder (Lubar, 1991; see also Monastra & Lubar, Chapter 30, this volume).

More recently, EEG feedback procedures purport to be successful in treating patients with a wide variety of other symptoms and disorders. The growth and scope of EEG biofeedback is partially reflected in the changes in this text now, with eight chapters compared to two in the third edition and one in the first two editions.

History and Development of EEG Biofeedback Technology

EEG biofeedback, sometimes referred to as "neurofeedback," began with the approach of enhancing a particular frequency band, generally alpha, as a means of achieving benefits associated with greater presence of that band in the EEG. When initial work began, some systems used conventional EEG systems, and augmented them with additional circuitry. Others were developed entirely "standalone," with amplifiers, processing circuits, and output devices (lights, speakers, etc.) as an integral part of the design. Early research used such custom-engineered systems to produce important initial results (e.g., Nowlis & Kamiya, 1970). As the field began to mature, manufacturers began to introduce products capable of measuring and feeding back EEG signals as their primary purpose.

A major limitation of early EEG feedback devices was that they filtered the desired band to indicate its presence but had no provision to ensure that out-of-band signals did not also contribute the feedback. For example, low-frequency signals due to theta waves, eye movement, motion artifact, or other non-alpha phenomena, if sufficiently large, could still produce enough output to trigger the reward. Similarly, high-frequency signals, including EMG and other artifacts, could also produce output within the desired training band, again imprecisely rewarding the trainee. As a result, early alpha trainers produced inconsistent results that contributed to a general lack of acceptance as useful professional tools. Early "recreational" alpha trainers, circa 1975, were primitive and not only trained alpha but also rewarded various artifacts such as muscle twitches and eye movements. (Interested readers can find photos of an early recreational alpha trainer, circa 1975, and an Autogenics 120 analog EEG trainer at *www.marksschwartzphd.com*).

During this time, professional biofeedback trainers were also being developed and applied. These remained entirely analog, and provided a display meter, and generally simple tones. A great deal of research was conducted using these devices, so that by 1978, dozens of studies including EEG biofeedback had appeared in the literature (Butler, 1978).

As EEG feedback equipment became more refined, and in particular when digital computers began to be used, it became possible to introduce "inhibit" bands, which were used to block feedback from occurring when these signals were present. The ability to withhold feedback when excessive slow or fast waves were present was a key step in the refinement of EEG biofeedback, and made it possible to produce useful and consistent clinical results. The use of these outer "guard" bands became very common and produced a generation of feedback trainers that accurately rewarded the desired EEG frequency components, without providing false feedback due to artifacts (Ayers, Sams, Sterman, & Lubar, 2000).

Early PC-based EEG biofeedback systems were implemented on platforms such as the Apple and IBM PC, and used simple "text-based" operating systems. Supplementary graphics and sound were generally very simple, yet effective. With the introduction of Windows and the Apple Macintosh, software became increasingly sophisticated. It became possible for programmers to incorporate advanced signal processing, graphics, video, multimedia, interactive games, and other capabilities, further enriching the feedback and improving responses.

Computers were used for delivering EEG biofeedback as early as the late 1970s. However, the processing speed was insufficient to keep up with the signal processing demands, which limited their utility It was not until the second and third generations of processors, when math coprocessors became available in the mid-1980s, that it was possible, for example, to perform a 256-point fast Fourier transform (FFT) in substantially less than a second. In the 1990s, computer speed became fast enough to provide real-time signal processing and adequate displays for useful training.

During the evolution of these techniques, certain aspects became paramount and hotly debated. Among these was "response time," which was construed to mean "the delay between the time something happens in the brain and the time it appears on the screen." While apparently straightforward, this definition cannot really be applied as such. In the world of real-time signals, digital filters, frequency transforms, and such, signals do not simply "come and go." Rather, they wax and wane, have varying amplitudes and time courses, and responses are analog, or graded, not simply on or off. As a result, it is necessary to consider filter response and other factors in evaluating system capabilities. In an early Windows-based EEG biofeedback system (Ayers) there was one enhance band (labeled "Facilitate") and one inhibit band (see examples at *www.marksschwartzphd.com*).

The response curve shown demonstrates that in order to respond to the narrow bandwidth of the 15.0–18.0 Hz range, the filter requires several cycles of the input wave in order to respond. This response characteristic is identical to that seen with analog filters. In other words, while digital processing provides benefits in the form of programmability, flexibility, and exotic displays, it cannot violate the basic laws of physics, and the ability to respond to EEG waves is in principle the same in digital as it is in analog systems.

Currently, most EEG biofeedback systems are PC-based. Thus, the hardware typically consists of an amplifier/digitizer ("encoder") that transmits EEG data to the PC in a digital form. From then on, the system depends entirely on the PC software, which can consist of thousands of lines of software code, developed over many programmer years of effort. EEG biofeedback has thus followed the trend of many other industries that have become dominated by software issues, and follow an aggressive and rapid evolution spurred on by continuous competition and the continual entry of new developers.

With the flexibility of computerized EEG biofeedback (Collura, 1995), seemingly rigid rules have been stretched and even broken. For example, with the introduction of multiple frequency bands for analysis and the ability to either reinforce or to inhibit any of them, a variety of creative protocols emerged.

Based on principles of learning theory, different methods of adjusting thresholds exploit different aspects of the nervous system having to do with perceived rewards, motivation, level of difficulty, and so on. Where computerized EEG biofeedback systems have excelled is in the use of complex rules to compute and deliver feedback, and the control of engaging and meaningful displays such as animation, video, games, and various types of specially designed software. The use of computerized signal processing has also allowed the introduction of a plethora of alternative methods and approaches, embodying physiological and mathematical concepts including nonlinear systems, chaos, coherence and stability, synchrony, self-adaptive systems, and normative databases.

Some EEG biofeedback systems appeal to concepts generally derived from "quantum physics," "subtle energy," and other seemingly esoteric areas. While these include systems that are well studied and published, there are others that appeal more to an article of faith than to peer-reviewed studies.

One element that has carried forward from initial systems, and continues to be in contention, is the issue of "monopolar" versus "bipolar" recording. Depending on whether the EEG is referenced to a neutral site or to another active site, the type of information available is profoundly different, and impacts the ability to train synchrony, connectivity, and other brain properties (Collura, 2009; Fehmi & Collura, 2007).

Early Investigations Leading to Neurofeedback

Our aims in this section are to (1) describe some of the early work that led to the field of research and therapeutic application of EEG biofeedback/neurofeedback and (2) address the question of what internal behaviors or private experiences are involved in learning to produce changes in specific EEG measures with the aid of neurofeedback.

My (Kamiya) research with the EEG was conducted to pursue questions concerning relationships between the EEG of persons and their consciousness. This interest in EEG research developed when I was working in the sleep laboratory of Nathaniel Kleitman and his student and research assistant William Dement, at the University of Chicago. It was from that laboratory that Aserinsky and Kleitman (1953) and Dement and Kleitman (1957) published the pioneering papers that indicated dreaming during sleep usually was accompanied by specific changes in the sleeping person's EEG and eye movements as monitored by the electrooculogram (EOG). Their papers did much to put private experience on the scientific map. Kleitman generously offered me the use of his laboratory to conduct some studies of my own. Dement taught me the technology of EEG and EOG recording of sleeping subjects. I completed a study on other physiological concomitants of drowsiness and sleep (Kamiya, 1961). My student and colleague, Johann Stoyva, joined me in the laboratory. In addition, in response to confusion and disagreements in the field on the problem of how to interpret the occasional fact that reports of dreaming would occur despite the absence of their EEG and EOG indicators, and the absence of dream reports when the EEG and EOG indicate dreaming had occurred, we published an analysis of the logic of the relations between verbal reports and physiological indicators as convergent indicators of private events such as dreaming (Stoyva & Kamiya, 1968). This problem is worth mentioning here because it arises in connection with the validity of the evidence of any sort of private experience, not just dreams. In the course of preparing a subject for all night recording with EEG and EOG electrodes, I always conducted a test of the EEG on the polygraph for a minute while the subject was still awake to make sure that all the electrode contacts with the scalp provided clean traces. It was during these tests that I noticed the irregularly timed appearance and disappearance of the EEG alpha rhythms. I wondered if they were related to any features of the consciousness of the person. How this interest led to the development of methods for studying that possibility, and eventually to the adoption of the method by others in the treatment of neurological disorders, is described in what follows.

There are wide variations in the characteristics of the trains of alpha rhythms. The question that motivated me was whether there are subjective concomitants associated with the moments when alpha rhythms are present as opposed to when they are absent. Might there be a difference in the feel or mental activity between the two EEG states in the relatively short-term alternations between the two that occur several times a minute? Considering what is known about conditions affecting alpha would help provide hints toward an answer. (For more on alpha rhythms, see *www.marksschwartzphd.com*).

Later, when I joined the Department of Psychiatry at the University of California at San Francisco (UCSF) in 1961 and moved my laboratory equipment there, I added an improvement over the on-or-off character of the feedback in earlier studies. A continuously graded tone volume from silent to loud now reflected the 1-second moving average amplitude of alpha, thus improving the information in the signal. The participant now could monitor his or her performance more accurately. We also changed the score presented every minute from total time of alpha above threshold to the average amplitude of alpha for the minute.

With these improvements in the feedback, the performance of the trainees improved, and interest level was maintained. I believe the several reported failures by other investigators to replicate the results we had obtained showing increases in the average trainee of alpha relative to initial baseline scores were, in many cases, due to inadequate equipment. But a major part of the reported failures of replication to train increases in alpha amplitude was due simply to insufficient total duration of training, as discussed by Hardt and Kamiya (1976) and Ancoli and Kamiya (1978). Several of the reported failures simply reflected the stopping of training after one or two sessions. In our laboratory we found that the first and second training sessions, with each session lasting about 45 minutes, resulted in average scores actually lower than the initial session baselines for each session. Plotting the average performance over six sessions of training, we saw a substantial drop in alpha relative to baseline scores in the first session, followed by a gradual increase in performance across sessions until the third session, when the trial scores and session baseline scores were about the same. It was not until the fourth session was reached that the trainees had increased their performance sufficiently to exceed their baseline for that session.

At least one factor, probably the major one, to account for the puzzling drop in performance relative to the session initial baseline and slow recovery across three sessions is that the challenge to find a mental state, feeling, and so forth, requires a busy mind in search mode, but that reduces alpha activity. Many a trainee has commented on the fact that trying to solve how to increase the tone level served only to reduce it. It is also possible that the lack of progress is perceived as failure by the trainee, and the resulting ego-threat and anxiety cause more alpha reduction. Some of the trainees' comments may best describe the situation: "The harder I try, the more the tone goes away"; "I gave up trying to increase the tone, and damned if it didn't get louder"; "I seem to do best when I just wait and let it come on by itself and be happy when it does."

Overall, it seems that even though verbal descriptions of the two states tend to agree among trainees, and tend to support descriptions made by earlier investigators, I believe that the use of everyday language has its limits as a way of characterizing the subjective experiences associated with the two states, particularly the state of alpha dominance. In short, the results indicate that it is far easier to detect a difference between these two brain states than it is to be able to describe what comprises the difference. However, it is also possible that learning to discern that there is a difference between alpha and non-alpha is only a first stage of coming into awareness of what the factors behind the difference are.

The best hint yet of an answer to the question posed by our results may come from another experiment that I had completed earlier. Because it might be that the apparent rise in alpha in the feedback experiment with the tone was at least to some degree due to the trainee becoming accustomed to the laboratory over repeated session, I gave new trainees alternating blocks of alpha-increase trials with alpha-decrease trials. I used five 1-minute increase trials, providing a quantitative score of alpha output after each minute. Then I delivered five 1-minute trials to decrease their alpha tone, also with a score of alpha output after each minute.

The subjects now learned to increase and decrease their scores quite efficiently (Kamiya, 1968). It seemed more helpful in sharpening their differentiation of the two in their verbal reports than the task given them earlier to only increase alpha amplitude. It is possible that the improvement reflects an increased opportunity to sense the difference between the two states by having them alternate within close temporal sequence the internal behaviors or mental states that are instrumental in producing the two states.

Applications of the Method to Clinically Relevant Physiological Measures

The field of EEG feedback or neurofeedback has not been particularly concerned with research issues such as the ones I (Kamiya) have been describing. Instead, rather quickly it became clear that the method of feedback training could yield some immediately practical results in the clinic as a method of treating neurological and psychological disorders that were known to be related to specific characteristics in the EEG. The fields of neurofeedback for the treatment of epilepsy and attention-deficit/hyperactivity disorder (ADHD) are two of the best examples. Sterman led the way in neurofeedback for treating epilepsy when he and Wyrwicka (Wyrwicka & Sterman, 1968) reported that in cats, the Sensory Motor Rhythm, their name for a burst of synchronized EEG activity over the motor cortex in an awake animal, could be brought under control by operant conditioning. The same sensory motor rhythm, when brought under operant control by humans, was found to suppress epileptic seizures (Sterman & Friar, 1972). Lubar and Shouse (1976) reported that a hyperkinetic child could be treated successfully with sensory motor rhythm training, thus starting the use of the method for the treatment of ADHD in many different laboratories and clinics, including that of Michael and Lynda Thompson (1998). Thompson and Thompson (2003) have since published a comprehensive book, *The Neurofeedback Book*, that has become a standard reference, as well as an aid for training therapists in the methods of EEG. The investigators who have worked and published their results in these fields for several decades now, led by Sterman, Lubar, the Thompsons, and several others have developed protocols that will eventually revamp the thinking of the medical fields toward neurofeedback as a treatment alternative to traditional pharmaceutical or surgical approaches.

CYBERNETICS

The term "biofeedback" is a shorthand term for external psychophysiological feedback, physiological feedback, and sometimes augmented *proprioception*. The basic idea is to provide individuals with increased information about what is going on inside their bodies, including their brains.

The field that deals most directly with information processing and feedback is called *cybernetics*. A basic principle of cybernetics is that one cannot control a variable unless information is available to the controller. The information provided is termed "feedback" (Ashby, 1963; Mayr, 1970).

Another principle of cybernetics is that feedback makes learning possible. Annett (1969) reviewed the evidence for this principle. In applied biofeedback, individuals receive direct and clear feedback about their physiology. This helps them learn to control such functions. For example, from a surface EMG instrument, persons receive information concerning their muscle activity. This helps them to reduce, increase, or otherwise regulate their muscle tension.

From a cybernetic perspective, operant conditioning is one form of feedback. It is feedback provided in the form of positive or negative results of a particular behavior. The point is that another significant contribution to the development of applied biofeedback is an information-processing model derived from cybernetic theory and research. Proponents of this model in the field of biofeedback include Brown (1977), Anliker (1977), Mulholland (1977), and Gaarder and Montgomery (1981).

CULTURAL FACTORS

Several cultural factors have contributed to the development of applied biofeedback. The gradual merging of the traditions and techniques of the East and West is one major factor. The rise in popularity of schools of meditation was an expression of a cultural change and provided a context in which applied biofeedback developed. Yogis and Zen masters reportedly alter their physiological states significantly through meditation. Related phenomena presumably occur in some forms of biofeedback experiences. Therefore, some have referred to biofeedback as the "yoga of the West" and "electronic Zen."

Within the United States, there are other cultural factors adding to a *Zeitgeist* encouraging biofeedback applications. These are the heightened costs of health care and the resulting need for more efficacious and cost-effective treatments. In addition, it is commonly recognized that pharmacotherapy, with its many benefits, is of limited value for certain patients. Some patients cannot take medications because of untoward side effects; many patients avoid compliance; others prefer not to consume medications; and some physicians deemphasize pharmacotherapy.

Perhaps even more significant is the current popular public health emphasis on prevention. The movement toward wellness has continued to grow since the 1960s. Practitioners of holistic health also emphasize self-regulation and self-control. The result of these emphases is that more people are involving themselves in lifestyle changes to regulate their health. These changes include enhancing physical fitness, avoiding caffeine and nicotine, reducing or stopping alcohol use, and pursuing better weight control. More people are thus assuming increased responsibility for their physical, as well as their mental and spiritual, well-being. In addition, more people are accepting responsibility for their recovery from illness. Many believe that biofeedback therapies facilitate and fit well into these efforts at greater self-regulation, wellness, and growth.

PROFESSIONAL DEVELOPMENTS

Also adding to the development of applied biofeedback are the organizations of professionals engaged in research and clinical, educational, and performance enhancement applications. Issues considered here include the professional organizations themselves, the status of the literature in this field, the professional journal of the primary organization (and the journal's name), and finally, the scope of the field.

Professional Organizations

Homer's epic poem *The Odyssey* served as a metaphor for the past, present, and future of biofeedback and applied psychophysiology. From the title of this epic, an "odyssey" has come to mean any long series of wanderings, especially when filled with notable experiences, hardships, and the exploration of new terrain. Just as Homer's Odysseus experienced setbacks but was ultimately successful in his journey to reach home, the journey of psychophysiological self-regulation with biofeedback has experienced and will continue to experience setbacks and successes. The Biofeedback Society of America (BSA) was entering its 20th year, thus completing one full generation of development, when similar words were first delivered (M. S. Schwartz, 1988). Twenty years constitute one generation, or the average period between the birth of parents and the birth of their offspring. Thirteen years then remained until the year 2001, the date of the famous book and movie *2001: A Space Odyssey*. However, our field does not seek the universality of something as monolithic as Arthur C. Clarke's and Stanley Kubrick's odyssey.

The Association for Applied Psychophysiology and Biofeedback and Its Various Names

HOW THE JOURNEY BEGAN

The Biofeedback Research Society (BRS) was formed in 1969, largely by a handful of research psychophysiologists. After 6 years, the BRS became the BSA, with both an experimental and an applied division. Age 6 is about the age at which children go through the transition from home to school; similarly, the scope of the organization and the field broadened into applied areas. This change in name reflected the growth and importance of applied aspects.

HOW THE JOURNEY CONTINUED

At age 19, as a result of the field's expanding scope, the BSA went through its second transformation—into the Association for Applied Psychophysiology and Biofeedback (AAPB; *www.aapb.org*). This is about the age at which many students graduate to institutions of higher learning. The organization returned to some of its roots in psychophysiology at the same interval. The consistency with the journey metaphor first struck M. S. Schwartz (1988) then, as Odysseus also took 20 years to return home.

As later reported by M. S. Schwartz (1999a),

> the name . . . change was a hotly debated topic. Many argued for a need to expand the implied scope of the organization. One factor was that most practitioners utilized a wider array of therapy methods than biofeedback. Presentations at the annual meetings of the BSA encompassed much more than biofeedback. Researchers at universities . . . maintained that the term biofeedback alone was not viewed as sufficiently credible by some individuals and that this hampered their abilities to publish their research in some quality journals and to obtain external research funding. The researchers further contended that the term "biofeedback" was insufficient for them to obtain the kind of recognition they needed in their academic departments. Thus, both applied practitioners and researchers were contending that a name change was needed.
>
> Psychophysiology was the birthplace of the field of biofeedback, and so it was time to return to these roots. The emphasis was placed on the term applied to distinguish it from [its] grandparent organization and field, the Society for Psychophysiological Research.
>
> Many members of the BSA . . . argued for dropping the term biofeedback but the supporters of the term successfully argued for the preservation of the term. . . . The term "applied psychophysiology" reflected the evolution of science and clinical practice. (p. 3)

The AAPB continues to be a productive, intellectually stimulating, useful, scientifically sound, and vibrant organization. There are several Interest Groups, Sections, and Divisions, including Sections for Applied Respiratory Psychophysiology, Educational, International, Mind–Body, Optimal Functioning, and Performing Arts Psychophysiology. There also now is a section for the U.S. Stress Management Organization, which is part of the International Stress Management Association (ISMA) with another interesting history dating from 1973, with illuminary founders Edmund Jacobson, F. J. McGuigan, and Marigold Edwards. Prior names for the international organization included the International Stress and Tension-Control Association and the International Stress Management Association (ISMA). The Neurofeedback Division and the sEMG/SESNA (Surface Electromyography Society of North America) Division reflect the two major modalitites and areas of biofeedback. Each of these has major tracks at the Annual Meeting of the AAPB.

Disagreement occasionally still arises about the most appropriate name for both the membership organization AAPB and its journal (see below). Some occasionally argue for dropping the term "biofeedback," but those who advocate retaining the term "biofeedback" in the names of the organization and journal focus on the established place of this term in the minds of professionals and the lay public, as well as on its history, brevity, and ease of communication.

Other Related Membership Organizations and Groups Sponsoring Meetings

Another national membership organization, the American Association of Biofeedback Clinicians, started in 1975 but went out of existence in the late 1980s. This left the BSA, now the AAPB, as the major organization with a major emphasis on biofeedback.

Biofeedback's impact is growing and spreading beyond the borders of the United States, as evidenced by the rise of the Biofeedback Foundation of Europe (BFE) (*www.bfe.org*). This excellent, international organization has hosted an annual meeting, featuring indepth workshops and scientific sessions, since 1996.

Since 1995, with the resurgence and expansion of EEG biofeedback, a specialty organization, the International Society for Neurofeedback and Research (ISNR; *www.isnr.org*) has become a major organization in this area. The ISNR was formed in response to the need for a group that was undividedly focused on EEG biofeedback. There had been previously created, within the AAPB, an "EEG Division" that attempted to serve the needs of this community. However, the influence of those primarily interested in peripheral (or "traditional") biofeedback was considered by some to be diluting these efforts, and it motivated certain individuals to create a new entity. Like the AAPB, its name and focus has evolved over time, but much more quickly. ISNR is an outgrowth of the Society for the Study of Neuronal Regulation, founded in 1993, whose name was shortened in 1998 to Society for Neuronal Regulation for simplicity, and then changed again in 2002, to the International Society for Neuronal Regulation. In 2006, it was renamed ISNR "to better reflect the fact that members of the society now came from all parts of the globe, not just North America and that research is a critical function of the society" (*www.isnr.org*). The ISNR also provides publications, research support, education, and an annual meeting.

Each of the aforementioned organizations has excellent websites with extensive and useful information.

The Biofeedback Certification International Alliance

The Biofeedback Certification International Alliance (BCIA), previously known as the Biofeedback Certification Institute of America, is a professional organization that has greatly influenced the continued development of the field. As its name indicates, the BCIA maintains a credible credentialing program. Before 1979, credentialing was in the hands of a few state biofeedback societies. These societies, well-meaning as they were, suffered from the understandable problems of small groups of professionals who typically had little or no training and experience with the complexities of credentialing. Thus, there was considerable variability in the credentialing across states. In most states, there was no credentialing at all or even the hope of any.

Ed Taub, then president-elect of the BSA, had the foresight and wisdom to inspire the development of an independent, credible, nationwide credentialing program. The BSA sponsored and supported the official establishment of the BCIA (named by Bernard Engel, later the first chair of the BCIA board) in January 1981. Three months later, when Engel became President of the BSA, he graciously relinquished the chair of BCIA to M. S. Schwartz. The BCIA evolved with more stringent criteria for education, training, experience, and recertification. Professionals continue to seek and earn the BCIA credential as the only credible one of its kind.

In recent years, another so-called credentialing organization arose in association with instrumentation its members refer to as "biofeedback," but all credible professionals known to at least the first author consider this group or what its members call biofeedback to be inaccurate or to lack credibility and not worthy of mention in this chapter or book.

Although the BCIA holds primacy in credentialing, educational opportunities exist in many undergraduate and graduate courses in biofeedback. Private training programs and workshops are offered by national, state, and regional professional organizations, as well as some biofeedback companies/distributors. There are also many companies manufacturing biofeedback instrumentation, and several "distributor" companies selling and servicing a variety of instruments from different manufacturers.

The Journey of a Family or Separate Journeys?

All professionals in this field share some joint responsibility and custody for the young adult we call "biofeedback and applied psychophysiology." Some professionals proceed on their own individual journeys; they seek their own destinations, their own Ithacas, instead of common ones. However, the AAPB continues as the leading administrative, facilitative, educational, and coordinating member organization dedicated to integrating professional disciples and conceptual frameworks that involve varied scientific and applied areas of applied psychophysiology and biofeedback. It is the nuclear family for biofeedback.

Status of the Literature in the Field

The number of publications is one barometer of the history, growth, and possibly the future of a field. The first bibliography of the biofeedback literature (Butler & Stoyva, 1973) contained about 850 references. The next edition, 5 years later, listed about 2300 references (Butler, 1978). Thousands more have appeared since then (Hatch, 1993; Hatch & Riley, 1985; Hatch & Saito, 1990). There are dozens of papers published each year in non-English-speaking countries, including Russia (Shtark & Kall, 1998; Shtark & Schwartz, 2002; Sokhadze & Shtark, 1991), and many others are published in Europe, Israel, and elsewhere.

Note that there are dozens of papers published each year in non-English-speaking countries. For example, the important Japanese literature was still in its early stages in 1979, but rapidly increased in the 1980s (Hatch & Saito, 1990; Shirakura, Saito, & Tsutsui, 1992). Their leading journal on biofeedback, *Japanese Journal of Biofeedback Research,* is nearing its 40th volume. There is also a rich history of research publications and clinical applications in Russia and other countries that were formerly part of the USSR (Shtark & Kall, 1998; Shtark & Schwartz, 2002; Sokhadze & Shtark, 1991). This foreign literature is not well known in the United States.

The Primary Journal, Its Name, and Other Publications

A measure of the maturity of a field is the existence and quality of its primary professional journal(s). The journal *Biofeedback and Self-Regulation*, published by Plenum Press, was started in 1976. The journal's name was changed to *Applied Psycho-*

physiology and Biofeedback as of Volume 22, in 1997. The editors, board, and publisher noted that "the journal has long had a broader focus than the title implied, and this new name more accurately reflects its expanded scope" (Andrasik, 1997, p. 1). Frank Andrasik has been the Editor-in-Chief since 1995, having followed many notable prior editors—Johann Stoyva, the first editor, Al F. Ax, coeditors Edward B. Blanchard & Mary R. Cook from 1984 until 1992, and Robert R. Freedman until 1995. It is still the major publication in this field. However, AAPB also publishes another very useful and important publication, called simply *Biofeedback*. For the past several years, with Donald Moss, as Editor-in-Chief, this has become an excellent quarterly publication. Another noteworthy journal is the *Journal of Neurotherapy*, which focuses on EEG biofeedback/neurofeedback.

DEFINITIONS OF BIOFEEDBACK AND APPLIED PSYCHOPHYSIOLOGY

Historical Review of Definitions

The history of biofeedback has witnessed many definitions. Olson (1987, 1995) noted 10 definitions starting from 1971. In the second and third editions of this text, Schwartz and Schwartz (2003) elaborated and discussed various historical definitions; the models from which they were derived; and the issues, elements, and factors involved in prior definitions. For example, whether or not the specific feedback signals as such result in changes and at what level does the signal become biofeedback, per se, was a focus of much debate in the 1980s. See the invigorating exchange and debate between Furedy (1987) and Shellenberger and Green (1987), a valuable and appreciated attempt to moderate and create perspective by Rosenfeld (1987), and the review and discussion of this by Schwartz and Schwartz (2003).

Some persons might still consider these topics interesting. However, we decided to deemphasize these topics in this edition partly in view of the 2008 official definition (AAPB, BCIA, and ISNR) (Schwartz, 2010) presented and discussed later in this chapter. This was done chiefly to reduce confusion and not detract from the official definition.

Increased information and patient education are common elements in all models. We suggest a conceptualization that includes different levels and types of information received by patients during biofeedback sessions. This discussion acknowledges the contributions of G. E. Schwartz (1982, 1983), who emphasized the contextual, organistic, multicategory, and multicausal approach to understanding biofeedback.

Schwartz and Schwartz (2003) presented and discussed their multilevel patient education model involving seven levels or facets of information about biofeedback. Readers are referred to the third edition and to *www.marksschwartzphd.com* for a full discussion of this model. This model proposed that patient education is an active ingredient of biofeedback, regardless of the discipline within which it is used. This component is not explicitly included in the new and official definition but it is implicitly "in conjunction with changes in thinking" (Schwartz, 2010, p. 90).

Toward the First Official Definition of "Biofeedback"

By Olson's (1995) definition, a competent therapist is an important part of biofeedback therapies. Moreover, computerized biofeedback is like having a high-tech electronic chalkboard for teaching and a built-in ability to measure progress. It is up to the therapist to use this technology to be the best possible teacher and communicator. In essence, biofeedback, used in the broad sense of signals, explanations, and patient education, *provides missing or deficient information in the intervention context. This information is helpful for the patient/client, the therapist, or the interaction.*

One does not evaluate a school book when it is presented to students by itself. Some students have the following: sufficient motivation, sufficient capabilities, no significant interference, sufficient times and places to study, other resources to use as references, an experiential background conducive to independent learning, confidence in their ability, and a teacher for help if they reach an impasse. Therefore, some students do well with self-study and never need to go to class. Others need classroom instructions and review of the text. Some of these others need extensive text review—paragraph by paragraph, page by page, and chapter by chapter. Some learn the material sufficient for earning an average grade. Others seek or "need" a grade of A. Some never learn much, if any at all. None of this is news. However, the point here is that we do not attribute the problem to the book unless it is written poorly and/or not tailored well to the student.

In Schwartz and Schwartz (2003) a comprehensive definition was offered that involved additions to Olson's (1995) definition.

The 2008 Official Definition

In mid-2007, the leadership of AAPB[5] started the process and coordinated the creation of the Task Force[6] on Nomenclature, a task force to develop an agreed-upon definition of "biofeedback" that would be endorsed by the three major organizations, the AAPB, the BCIA, and the ISNR. The task force's diligent work on this challenging project over several months culminated in a definition that was then submitted to the Boards of the three organizations that had contributed task force members. The Boards voted their agreement in 2008, and the definition became the first, official, agreed-upon definition in the field. The story of this process may be found in M. S. Schwartz (2010).

> 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. (Approved May 18, 2008, by the AAPB, the BCIA, and the ISNR).

A Definition of "Applied Psychophysiology"—Sort Of

Defining the term "applied psychophysiology" still remained a need, goal, and challenge as of 1998, several years after the name change for AAPB and its journal. As noted by M. S. Schwartz (1999a, p. 4), "One can only surmise that everyone apparently *knew* what applied psychophysiology meant. . . . What everyone apparently knew, no one had written. What everyone apparently knew, was unclear." It was the broader term, a rubric term, that subsumes biofeedback.

J. Peter Rosenfeld (1992), in his AAPB presidential address, was the first to address a definition of "applied psychophysiology." He identified some of its elements "and touched on elements of a definition" (M. S. Schwartz, 1999a, p. 4). Sebastian Striefel (1998), a later president of the AAPB, again raised the question of a definition of "applied psychophysiology" in his 1998 presidential address. At the same meeting, "Paul Lehrer, chairperson of the AAPB Publication Committee, convened an ad hoc committee to deal with a wide array of topics. . . . One of these topics was . . . the lack of a formal . . . definition of 'applied psychophysiology'" (M. S. Schwartz, 1999a, p. 4). The committee assigned the task of establishing an operational definition for the term. Apparently, no one thought to establish a task force. The AAPB asked one person to develop a definition (M. S. Schwartz, 1999a, 1999b).

A provisional definition was drafted and a paper documenting the rationale for each component was written. An array of notable and diverse professionals provided their critiques to the provisional definition in the initial paper by M. S. Schwartz (1999b). The author of the definition then prepared a response to the panel of independent critical reviewers (M. S. Schwartz, 1999b). The development of a definition that is acceptable to everyone is unlikely. Amendments and modifications were expected. The published discussions of the key elements, examples of topics included and excluded, rationales for these choices, critiques, and responses are best read in their original form. There is still no formal and agreed-upon definition of "applied psychophysiology"—only a tentative and certainly unofficial operational definition (M. S. Schwartz, 1999a, p. 5) presented here only for historical interest and, we hope, to motivate others to refine and shorten it.

> Applied psychophysiology reflects an evolving scientific discipline and specialty involving understanding and modifying the relationship between behavior and physiological functions by a variety of methods including noninvasive physiological measures. The term "applied psychophysiology" is a rubric encompassing evaluation, diagnosis, education, treatment, and performance enhancement.
>
> Applied psychophysiology includes a group of interventions and evaluation methods with the exclusive or primary intentions of understanding and effecting changes that help humans move toward and maintain healthier psychophysiological functioning. Applied psychophysiology involves helping people change physiological functioning and psychological functioning (measured, theoretical, and potential) and/or to achieve sensorimotor integration and motor learning within physical rehabilitation.
>
> The group of interventions use all forms of biofeedback, relaxation methods, breathing methods, cognitive-behavioral therapies, patient/client education, behavioral changes, hypnosis, meditative techniques, and imagery techniques (some commentators would add: *when directed at changing physiological functioning*). In some situations, dietary and other biochemical (nonmedication) changes and some

truth detection research and applications may be considered under the rubric of applied psychophysiology.

Evaluation methods use all forms of physiological measurements. The physiological functioning includes but is not limited to accurately measured changes in skeletal muscles, all autonomic physiology, breathing measures, biochemistry, electroencephalographic activity, both normal and abnormal and imaging techniques. Autonomic measures include electrodermal, skin temperature, blood pressure, heart rate, gastrointestinal motility, and vasomotor.

The interventions need to be part of or have implications for applications to humans. These could, but do not need to, involve the raw procedures and/or symptoms of medical and psychophysiological disorders.

GLOSSARY

Alpha wave activity. EEG activity (8–12 hz) commonly, but not always, thought to be associated with an alert but relaxed state.

Autonomic nervous system (ANS). The part of the nervous system that is connected to all organs and blood vessels, and transmits signals that control their functioning. It consists of two branches, the sympathetic and parasympathetic, which usually produce opposite responses. Once thought to be totally involuntary, it is now known to be under some significant voluntary control, although less so than the CNS.

Central nervous system (CNS). The part of the nervous system including human thought, sense organs, and control of skeletal muscles. Once believed to be totally separate from the ANS, it is now known to interact with the ANS.

Classical conditioning. Originating with Pavlov, the type of conditioning or learning that assumes that certain stimuli (unconditioned stimuli, or UCSs) evoke unconditioned or unlearned responses (UCRs) (e.g., acute pain evokes crying, withdrawal, and fear), and that other, previously neutral stimuli (conditioned stimuli, or CSs) associated with the pairing of these events develop the capacity to elicit the same or similar responses or conditioned responses (CRs).

Curarized animals. Animals intentionally paralyzed by the drug curare to control for body movements during visceral conditioning, such as biofeedback of heart rate.

Cybernetics. The science of internal body control systems in humans, and of electrical and mechanical systems designed to replace the human systems.

Electroencephalography (EEG). The measurement of electrical activity of the brain.

Electromechanical. A term describing devices that measure mechanical aspects of the body (e.g., position of a joint or degree of pressure or weight placed on it), rather than a property of the body (e.g., its direct electrical activity or temperature). Examples of these mechanical aspects include degrees that a person's knee bends after knee surgery, steadiness of the head of a child with cerebral palsy, and the weight pressure placed on a leg and foot by someone after a stroke. Instruments transform these mechanical forces into electrical signals.

Electromyography (EMG). The use of special instruments to measure the electrical activity of skeletal muscles. In recent years, also called "surface electromyography" and sometimes abbreviated as SEMG.

Extinction. The behavioral principle predicting that abruptly and totally stopping all positive reinforcements after specified behaviors will lead to the behavior's no longer occurring.

Fading. Gradually changing a stimulus that controls a person's or animal's performance to another stimulus. As a behavioral procedure, it does not always mean disappearance of a stimulus.

Fight or flight. Walter Cannon's well-known concept of the body's psychophysiological arousal and preparation for fighting or fleeing actual or perceived threatening stimuli.

Galvanic skin response (GSR). A form of electrodermal activity—increased resistance of the skin to conducting tiny electrical currents because of reduced sweat and dryness. Older term less ofen used now, but still accepted. Opposite of "skin conductance" (SC).

Insight-oriented psychodynamic theories and therapies. A wide range of psychological theories and therapies, starting from the time of Sigmund Freud. A basic assumption is that patients need to gain insight into the psychological origins and forces motivating their current psychological problems and behaviors before they can achieve adequate relief of symptoms.

Instrumental conditioning. Same as operant conditioning (see below). The behavioral theories and therapies originated by B. F. Skinner. For example, reinforcers are said to be instrumentally linked to the recurrence of behaviors.

Observational learning. Learning that takes place by means of the organism's observing another organism doing the task to be learned.

Operant conditioning. The same as instrumental conditioning (listed earlier), originating with B. F. Skinner. "Operant" means that a response is identified and understood in terms of its consequences rather than by a stimulus that evokes it. Stimuli and circumstances emit responses rather than evoke them, as in classical conditioning.

Proprioception. Perception mediated by sensory nerve terminals within tissues, mostly muscles, tendons, and the labyrinthal system for balance. They give us information concerning our movements and position. Examples include (1) the sense of knowing when we are slightly off balance; and (2) the ability to perceive (even with eyes closed) the difference between, and approximate weights of, objects weighing 5 ounces and 7 ounces held in each hand.

Psychophysiology. The science of studying the causal and interactive processes of physiology, behavior, and subjective experience.

Reinforcers. Events or stimuli that increase the probability of recurrence of behaviors they follow.

Schedules of reinforcement. Usually, forms of intermittent reinforcement of an operant behavior. A common schedule in life, and most resistant to extinction, is a variable-ratio schedule—one in which the number of times a reinforcement follows a specific behavior varies randomly, so the person or animal never knows when the reinforcer will occur. This contrasts with variable-interval, fixed-interval, and fixed-ratio schedules.

Sensorimotor rhythm. An EEG rhythm (12–14 Hz) recorded from the central scalp and involving both the sensory and motor parts of the brain, the sensorimotor cortex. Used in the EEG biofeedback of some persons with seizure disorders.

Shaping. A behavioral principle from operant conditioning, referring to procedures designed to help learning of complex new behaviors by very small steps. Also known as "shaping by successive approximations."

Single motor units. Individual spinal nerves or neurons involved in movement. Biofeedback training of single spinal motor neurons was a major advance in the late 1950s and early 1960s. This training requires fine-wire EMG electrodes.

Skeletally mediated mechanical artifacts. Artifacts in instrumentation-recorded signals that are caused by intentional body movements. Examples include moving a body part such as the head or neck during recordings of resting muscle activity, or clenching the teeth during EEG recordings.

Slow-wave activity. EEG activity (3–8 Hz) included in the frequency range often called theta activity, also reported as 4–7 Hz.

Vasomotor. Affecting the caliber (diameter) of a blood vessel.

Visceral learning. Learning that takes place by body organs, especially those in the abdominal cavity, such as the stomach and bowels.

Visceral reflexes. Reflexes in which the stimulus is a state of an internal organ.

Zeitgeist. The spirit or general trend of thought of a time in history. Often used to refer to a time in history when new ways of thinking and technologies are more likely to be accepted by the culture in question.

ACKNOWLEDGMENTS

We gratefully acknowledge and will always be thankful to R. Paul Olson for his earlier contributions to this chapter. His creativity and scholarly writing of the original version of this chapter continue to be the model we follow.

NOTES

1. Although the term "applied psychophysiology" is now usually given first in this pairing, the order is reversed here to relect the emphasis on biofeedback.

2. The 25th anniversary meeting of the primary professional membership organization, the Association for Applied Psychophysiology and Biofeedback (AAPB), was held in 1994. The commemorative *AAPB Silver Anniversary Yearbook* published for that meeting contains articles about the history and development of the biofeedback field and the organization. Reading it is enriching and informative. It is available from the AAPB, 10100 West 44th Avenue, Suite 304, Wheat Ridge, CO 80033; phone: 303-422-2615; fax: 303-422-889; website: *www.aapb.org.*

3. Note that this sentence appeared in the first edition of this book in early 1987. It does not seem to be a coincidence that the Biofeedback Society of America (BSA) went through the process of changing its name to include board meetings or other public or private meetings concerning the name change. The term was written into an early draft of this chapter several years before 1987.

4. "Health psychology" is a more recent field with similar roots and ties to behavioral medicine. The focus is more on prevention and health enhancement.

5. The AAPB Executive Board and, specifically and most notably, Aubrey Ewing, then President-Elect and Alan Glaros, the President, along with Executive Director Francine Butler, were the prime movers on the project. They coordinated with the leadership of two other major organization in this field, the BCIA and the ISNR.

6. See Schwartz (2010) for a list of the members.

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