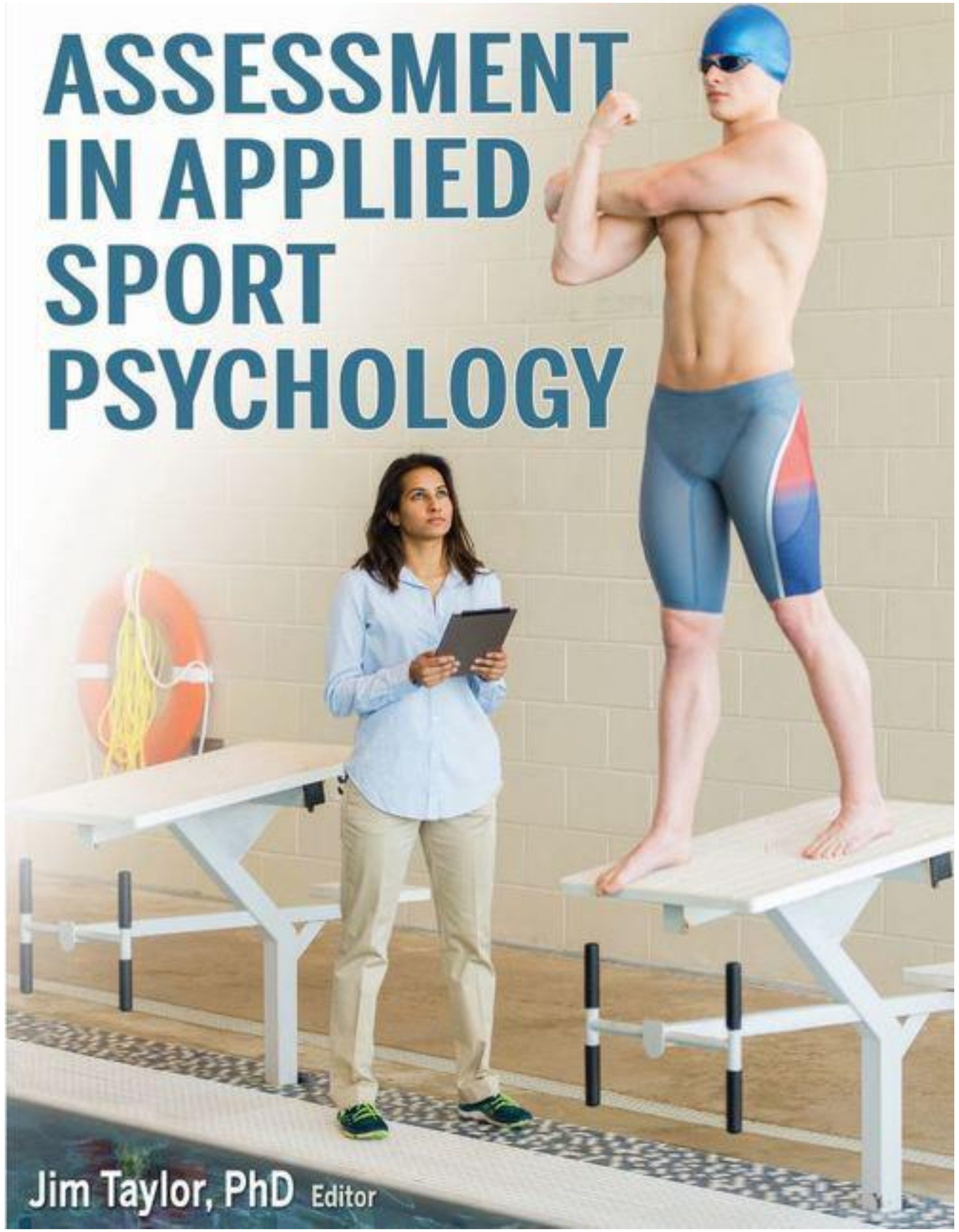


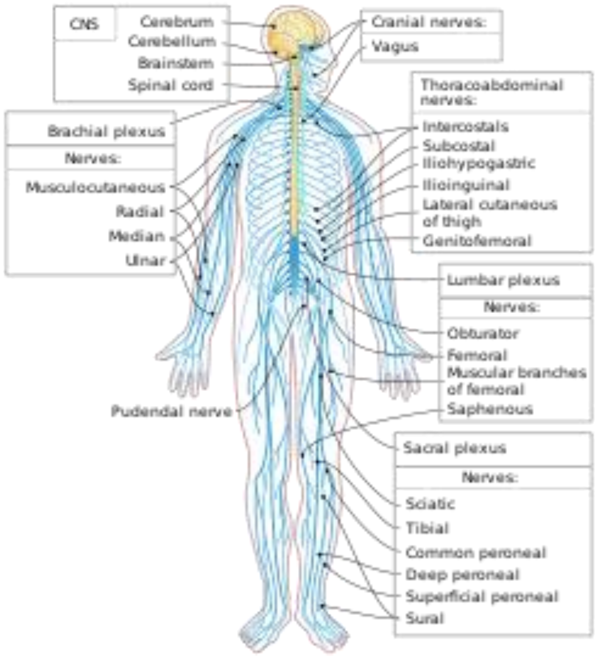
Chapter 10
Applied Psychophysiology: Using Biofeedback, Neurofeedback, and Visual Feedback

Hediyeh Dabagh

M.Sc. of Sport Psychology, University of Tehran(UT)

Responsible of iran's Brain Mapping Student Branch(IBMS)

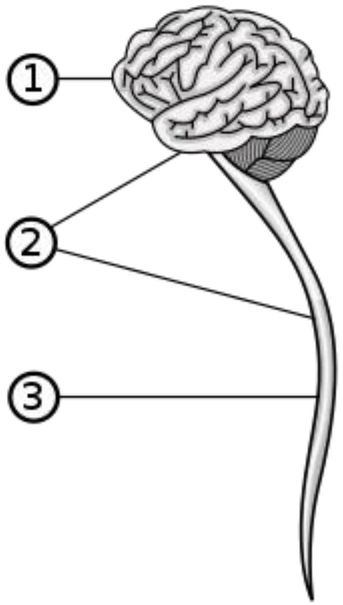
Biofeedback



Biofeedback refers to the feedback of PNS activity for the sake of enhanced awareness and influence over these functions. Psychophysiologists use sensitive electronic equipment to measure biological markers such as heart rate, HRV, skin conductance (SC), and peripheral temperature. When athletes are given assessment data in real time, it provides them with a means of expediting psychophysiological self-regulation.

The technology of biofeedback holds great promise for sport psychology practitioners, specifically for psychological skills training, stress management, and self-regulation. Reviews in the sport science literature have highlighted the benefits of biofeedback (Blumenstein, 2002; Zaichkowsky, 1982). *Biofeedback* is a comprehensive term that often includes neurofeedback. In this chapter, *biofeedback* refers to the feedback of PNS activity and *neurofeedback* refers to CNS feedback.

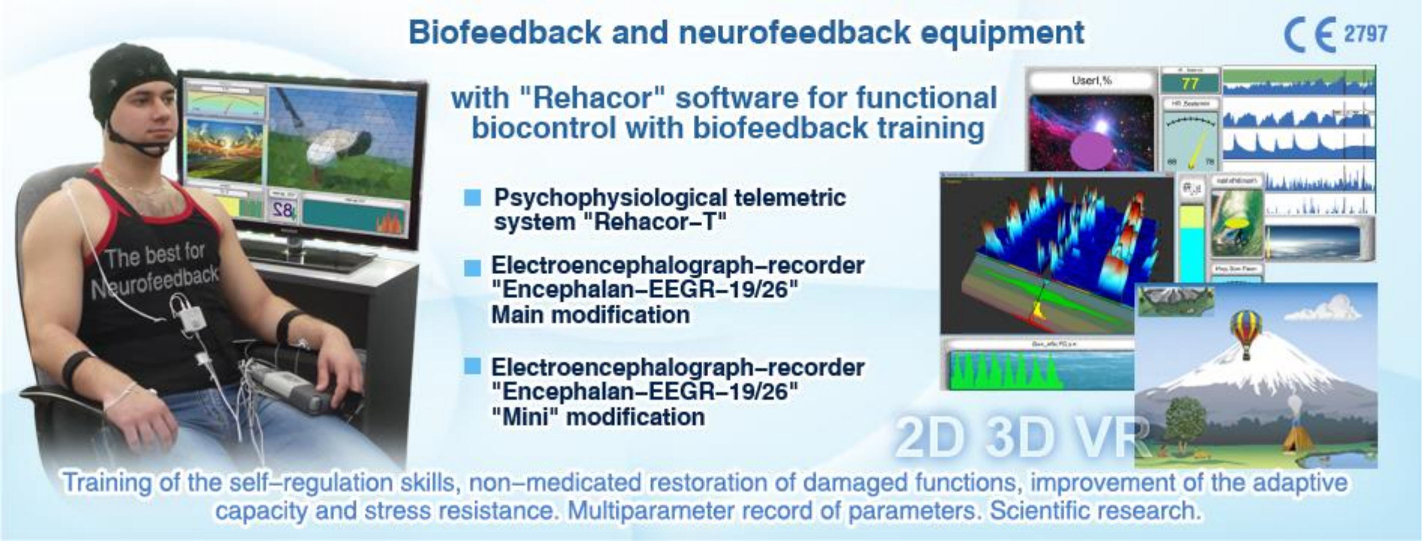
Neurofeedback



Neurofeedback refers to information gathered from neural activity in the brain for the purpose of increasing awareness and influence over these processes. Neurofeedback uses highly sensitive instruments to measure brain activity associated with athletic performance. When possible, athletes are monitored during their athletic performance. When this is not possible, athletes experience their performance through simulations such as video replay or imagery.

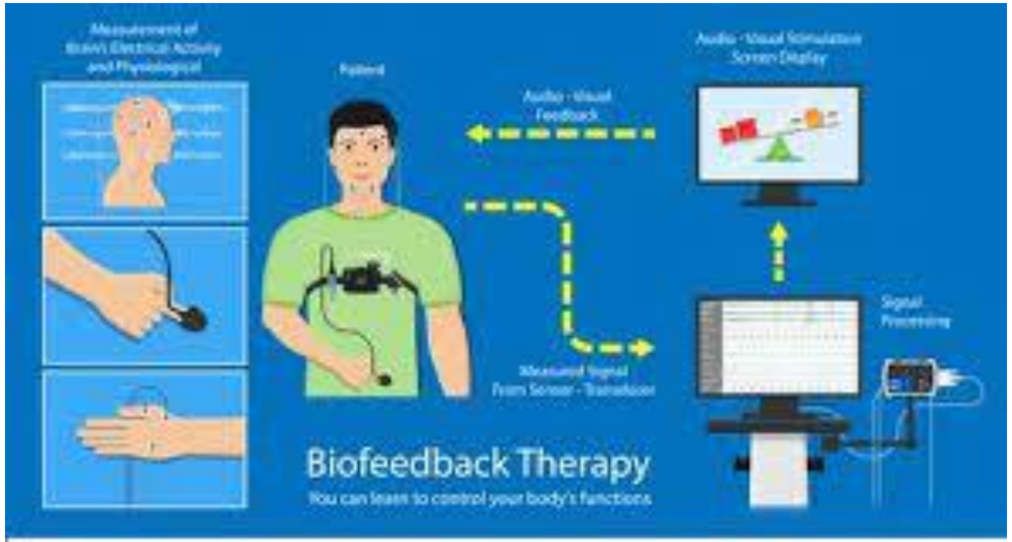
Biofeedback and Neurofeedback Assessment

Psychophysiological assessment and training tools, including biofeedback and neurofeedback, are increasingly integrated into sport psychology services for both professional and Olympic athletes (Beauchamp, Harvey, & Beauchamp, 2012; Blumenstein, Bar-Eli, & Tenenbaum, 1997; Collins, 1995; Dupee & Werthner, 2011; Lagos et al., 2011; Pusenjak, Tusak, Leskovsek, & Schwarzlin, 2015; Strack, 2003; Wilson & Peper, 2011; Zaichkowsky, 1982). In the biofeedback and neurofeedback domain, there are many clinical software packages designed for therapy and diagnosis (e.g., ADHD; Schwarz & Andrasik, 2003). However, in the optimal performance domain, fewer have been developed with the goal of performance enhancement in sport.



Biofeedback and Neurofeedback Assessment Modalities

Psychophysiological assessment and training are done with a polygraph. A polygraph is a machine that measures various physiological functions, or modalities. Sensors placed over the area of interest transmit signals to an encoder. The encoder samples the incoming data, digitizes it, and sends it to software, which displays it on a monitor. Athletes and sport consultants observe real-time measurement of psychophysiological processes at a sensitivity not otherwise possible.



Muscle Activation

SEMG measures muscle activation in microvolts (μV) using sensors placed on the skin over the muscle of interest. Monitoring muscle activation during movement and psychological tasks reveals maladaptive muscle habits, such as guarding, that reduce flexibility and energy efficiency. Ideally, resting muscle is inactive. Residual muscle tension indicates that athletes may benefit from training on muscle tension awareness. For example, athletes train to recognize and produce the right electromyography (EMG) level for the quickest reaction-time start in the 100-meter dash.

Skin Conductance

An electrodermograph measures the degree of electrical conductivity across the hand. Eccrine glands produce tiny amounts of sweat in response to sympathetic nervous system activation, which increase the electrical conductivity of the skin. Sometimes referred to as an *electrodermal response*, or *EDR*, skin conductance (SC) is measured in microsiemens (μS). SC is a measure of arousal, whether positively or negatively experienced. It is useful in assessing reactivity and quieting. SC is often used to reveal stress points in an athletic performance, either in anticipation or in review of the performance. For example, it can be used during start simulation training to increase an athlete's ability to maintain focus within a specified arousal threshold.

Temperature

Skin temperature is measured with a thermistor, usually placed on a finger. As blood vessels dilate or constrict, temperature increases and decreases accordingly. Hand cooling indicates sympathetically activated vasoconstriction. It is normal for hand temperature to cool in response to the presentation of acute stressors, and it is desirable for that cooling to slowly reverse into a warming trend during recovery periods. Athletes who practice learned hand warming modulate their stress response before performance and hasten their recovery afterward.

Respiration

Respirometers (strain gauges) indirectly measure mechanical changes in breathing. Of particular interest are the relative contributions of diaphragmatic breathing and thoracic breathing. Using the accessory muscles of breathing when not under conditions of exertion is often a sign of stress response. Monitoring the respiration rate of athletes before they start their routines can identify hyperventilation and excessive anxiety and can guide interventions.

Blood Volume Pulse

A photoplethysmographic sensor, placed on one finger or the earlobe, uses infrared light to detect blood volume changes in response to each heartbeat. Blood volume pulse (BVP) is a noninvasive measure of heart rate and HRV. BVP demonstrates rapid changes in heart rate in response to precompetitive anxiety and decreases in heart rate during rest and recovery. Though it is less accurate than electrocardiography, it is often more practical for applied use with athletes.

Electrocardiography

The electrical activity of the heart is recorded by several electrodes placed on the skin over the cardiac muscle. Electrocardiography (ECG) measurement of heart rate and interbeat variability is preferable to BVP for research–grade HRV assessment because it provides a clear signal for measurement. A measure of electrical activity, an ECG gives a precise measurement of the depolarization of cardiac muscle. In contrast, BVP is a measure of blood volume changes in the arteries and capillaries.

Heart Rate Variability

Heart rate variability (HRV) represents the ability of the heart to flexibly respond to situational demands. A dynamic equilibrium between sympathetic (excitatory) nervous system influences and parasympathetic (inhibitory) influences is associated with autonomic balance and emotional flexibility. Heart rate varies with breathing. Healthy, nonstressed hearts accelerate during inhalation (to capitalize on the influx of oxygen) and decelerate during exhalation. Slow breathing lengthens this cycle and increases the variability of the beat-to-beat interval. Measurement of IBI (interbeat interval) can be accomplished using ECG and measuring from peak to peak (the R spikes, as depicted in figure 10.1) or by using photoplethysmography (PPG) with the peaks of the BVP signal.

Figure 10.1 Sample R–R interval measurement in milliseconds, demonstrating variation in heartbeat intervals.

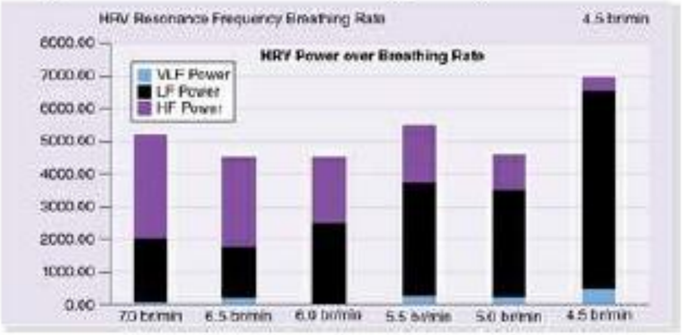
Reprinted, by permission, from Didier Combatalade, 2010, *Basics of HRV manual* (Montreal, Quebec: Thought Technology).

Athletes with high HRV are said to be recovered. Those with low HRV most likely need more recovery time between intense workouts for best training results.

Respiratory Sinus Arrhythmia

Respiration-driven changes in heart rate acceleration and deceleration are called *respiratory sinus arrhythmia*, or *RSA*. The breathing frequency at which RSA is greatest is called the *resonant frequency* and is associated with a state of calm readiness in athletes. This ranges from 4.5 to 7.5 breaths per minute for adults (Lehrer et al., 2013; Lehrer & Gevirtz, 2014). RSA assessment reveals the resonant breathing frequency for individual athletes by leading them with a breathing pacer through rates from approximately 8 breaths per minute to 4 breaths per minute. An example of an athlete's individualized resonance frequency report is illustrated in figure 10.2. The key to recognizing the resonance frequency in this figure is to look for the bar with the tallest *black* segment (Low Frequency component). In this case, it also happens to be the tallest bar in the figure.

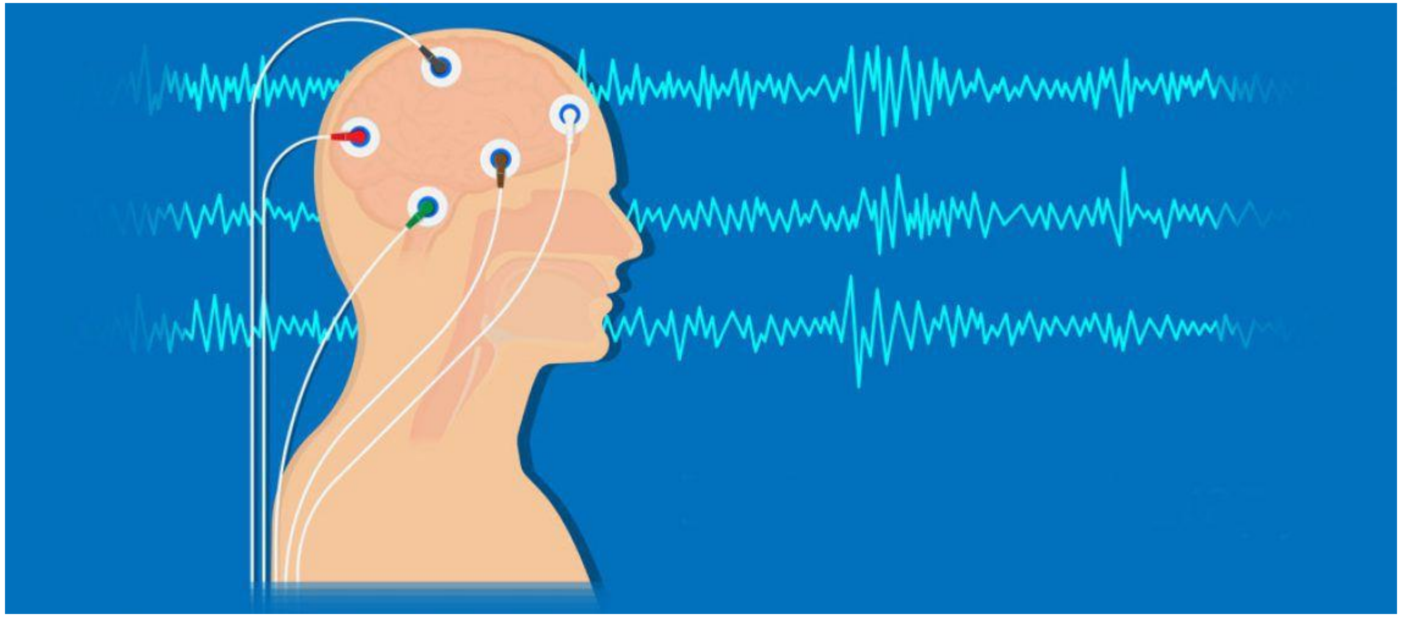
Figure 10.2 Resonance frequency assessment.



Reprinted, by permission, from P. Beauchamp, 2017, Peak Performance Suite.

Electroencephalography

In neurofeedback, electrodes are placed on the scalp to record the amplitude (in microvolts) of brain activity in that location in a process called *electroencephalography*, or *EEG*. The results are expressed in frequency bands (often represented by Greek letters) that reflect different types of thinking and attention (see table 10.1). For example, active problem solving correlates with the 15 to 18 Hz frequency band, whereas calm, focused attention correlates with activity in the 13 to 15 Hz band. By calculating the ratios between bands, you can obtain estimates of attentional and imagery abilities, efficient problem solving, and the tendency to try too hard or engage in self-judgment or rumination. (For a comprehensive treatment of EEG assessment and neurofeedback, see Thompson & Thompson, 2003.)



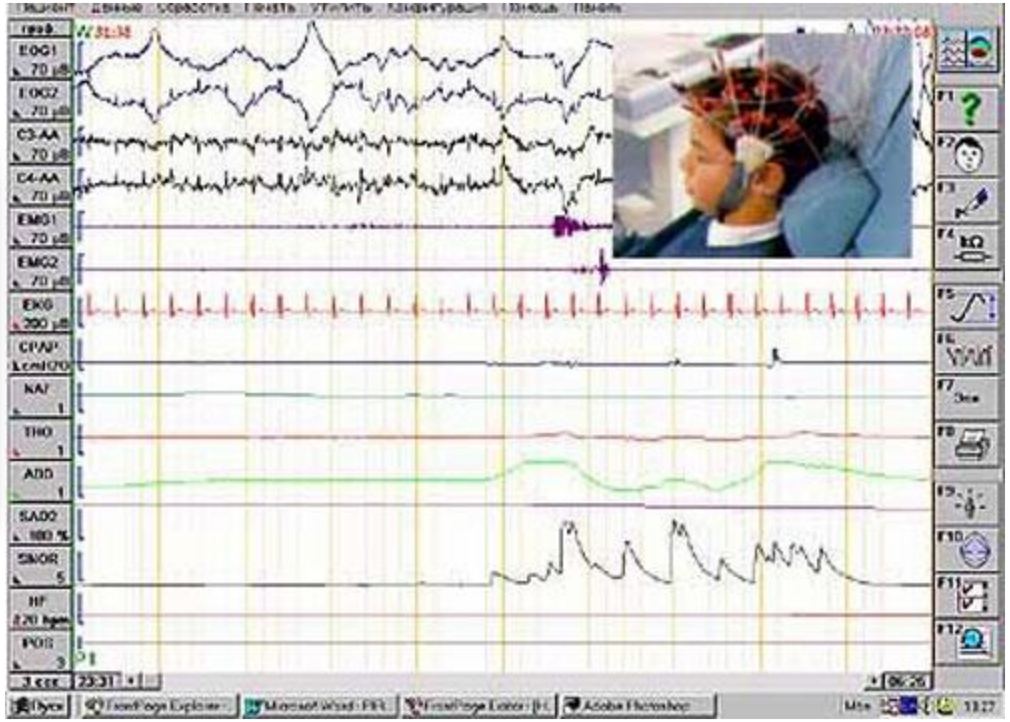
Electroencephalography

In neurofeedback, electrodes are placed on the scalp to record the amplitude (in microvolts) of brain activity in that location in a process called *electroencephalography*, or *EEG*. The results are expressed in frequency bands (often represented by Greek letters) that reflect different types of thinking and attention (see table 10.1). For example, active problem solving correlates with the 15 to 18 Hz frequency band, whereas calm, focused attention correlates with activity in the 13 to 15 Hz band. By calculating the ratios between bands, you can obtain estimates of attentional and imagery abilities, efficient problem solving, and the tendency to try too hard or engage in self-judgment or rumination. (For a comprehensive treatment of EEG assessment and neurofeedback, see Thompson & Thompson, 2003.)

Table 10.1 EEG Frequency Ranges for Sport Psychology Consulting

Theta 4-8 Hz	Low alpha 8-10 Hz	High alpha 11-12 Hz	SMR 13-15 Hz	Beta 15-18 Hz	High beta 19-22 Hz	Busy brain 23-25 Hz
Drifting, wandering mind, frustration disinhibition	Imagery, calm, relaxed	Calm, relaxed	Ready to pounce, sport ready	Processing information, scanning	Trying too hard, anxiety	Evaluation, rumination, negative thoughts

Adapted, by permission, from V. Wilson, *Optimizing performance and health suite.*



Biofeedback and Neurofeedback Training With Athletes

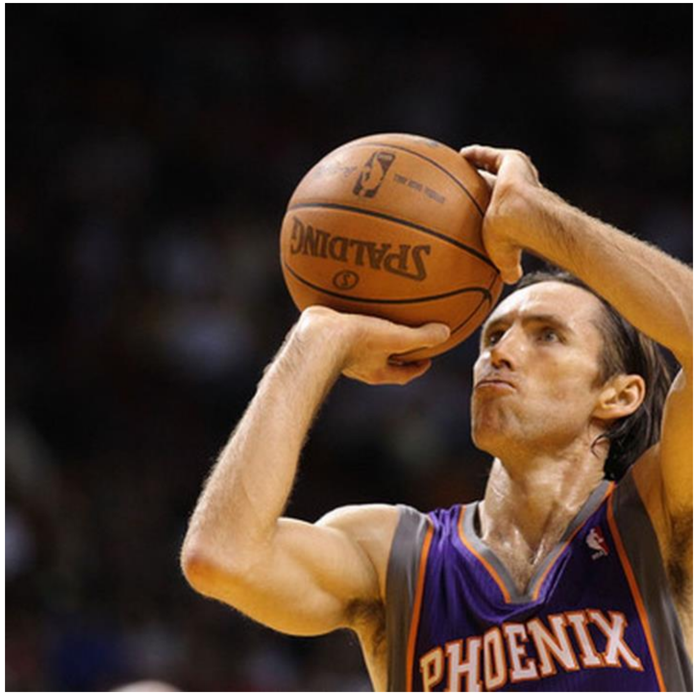
The purpose of these assessments is to identify problematic mental states, such as rumination, self-judgment, or worry, that interfere with optimal performance and subsequently target them in training. Existing abilities such as self-calming, focus, and imagery can also be augmented with biofeedback training. The principle behind training guided by psychophysiological assessment is that an increase in an athlete's ability to self-regulate arousal and attention improves performance in competition (for a review of biofeedback- and neurofeedback-related performance improvements, see Blumenstein, 2002, and Vernon, 2005). Biofeedback training with athletes generally starts in an office or lab, where the process of biofeedback is explained and initially experienced. In this controlled environment, athletes learn to become aware of their psychophysiological states and how to regulate them. Athletes progress through incremental levels of difficulty and improve their awareness and control over their psychophysiology. Physiological feedback is then gradually delayed and eventually removed to prevent dependence on feedback guidance and to promote self-sufficiency.

To facilitate transfer of this awareness and mastery from the office to more realistic sport situations, the training context begins to increasingly resemble the competitive context in which these skills will be used. Practicing changes in mental state with imagery of competitive situations, video of past performances, and actual performance simulations sets the stage for the transfer of these skills to the practice and competitive arenas. After this transition, athletes apply their new skills to their practice and competitive efforts until the skills become automatic in their training and

Assessment in Action

Neurofeedback and Target Sports

An EEG stress assessment identifies problematic areas of cognitive flexibility for athletes in target sports. Next, EEG monitoring while aiming and shooting, plus athlete self-report, reveals the cognitive experiences that distinguish good shots from less accurate ones. The results of these assessments guide the subsequent neurofeedback training. Practicing raising alpha waves and SMR and lowering beta waves, for example, increases the ability to shift into that mental state when desired. This cognitive shift is added to the preshot routine to improve accuracy and confidence.



Thank you for your attention