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### **Neurofeedback for the Enhancement of Athletic Performance and Physical Balance**

D. Corydon Hammond, Ph.D., ECNS, BCIA-EEG  
University of Utah School of Medicine

#### **Abstract**

Neurofeedback (EEG biofeedback) holds potential for retraining brainwave activity to enhance optimal performance in athletes in various sports. Neurofeedback has been shown to have potential for quieting the mind to improve performance in archery, for example. It can also be used to improve concentration and focus, to improve cognitive function and emotional control following concussions and mild head injuries, and it has untapped potential to increase physical balance in gymnastics, ice skating, skiing, and other areas of performance. Clinical examples are provided on the use of neurofeedback to improve physical balance and controlled research is called for.

**Keywords:** Neurofeedback, Biofeedback, Sport Performance, Performance Enhancement

**Corresponding author:** [Hammond@m.cc.utah.edu](mailto:Hammond@m.cc.utah.edu)

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# **Neurofeedback for the Enhancement of Athletic Performance and Physical Balance**

## **Introduction**

Research has been done for approximately 35 years on the use of biofeedback to modify EEG (brainwave) patterns. Initial research focused on relieving anxiety (Hammond, 2005a; Moore, 2000) and on the treatment of uncontrolled epilepsy (Serman, 2000), with the latter research including placebo-controlled, blinded studies. Since that time considerable research has been conducted on the use of neurofeedback (EEG biofeedback) in the treatment of ADD/ADHD (Monastra, 2005), and neurofeedback is being applied in treating many other brain-based clinical conditions such as head injuries, depression, stroke, and learning disabilities. Recent research has also documented the potential of neurofeedback in enhancing optimal performance in high level musical performers (Egner & Gruzelier, 2003) and in dance performance (Raymond, Sajid, Parkinson, & Gruzelier, 2005).

Neurofeedback training is brainwave biofeedback. Training generally consists of placing a couple of electrodes on the scalp and one or two electrodes on the earlobes. Then EEG equipment provides real-time, instantaneous audio and visual feedback to the subject about his or her brainwave activity. No electrical current is put into the brain. The brain's electrical activity is simply relayed to the computer. Ordinarily we cannot reliably influence our brainwave patterns because we lack awareness of them. However, when we can see a representation of our brainwave activity on a computer screen a few thousandths of a second after they occur, it gives us the ability to influence and change them through a process of operant conditioning. We are now literally able to recondition and retrain the brain. At first, the changes are short-lived, but the changes gradually become more enduring and with continuing feedback, coaching, and practice, improved brain functioning can usually be trained in most people and the changes are enduring. Electrode placements can be determined based on quantitative EEG brain mapping assessments, or in relation to areas of the brain associated with various functional roles (Joseph, 1996; Tranel, 2002) in relationship to the International 10-20 System of Electrode Placement (see Figure 1). There are now good textbooks on neurofeedback

(Demos, 2004; Thompson & Thompson, 2003), and high quality training is available through the International Society for Neuronal Regulation ([www.isnr.org](http://www.isnr.org)), the Association for Applied Psychophysiology and Biofeedback ([www.aapb.org](http://www.aapb.org)), and the American Board of Sport Psychology ([www.americanboardofsportpsychology.org](http://www.americanboardofsportpsychology.org)).

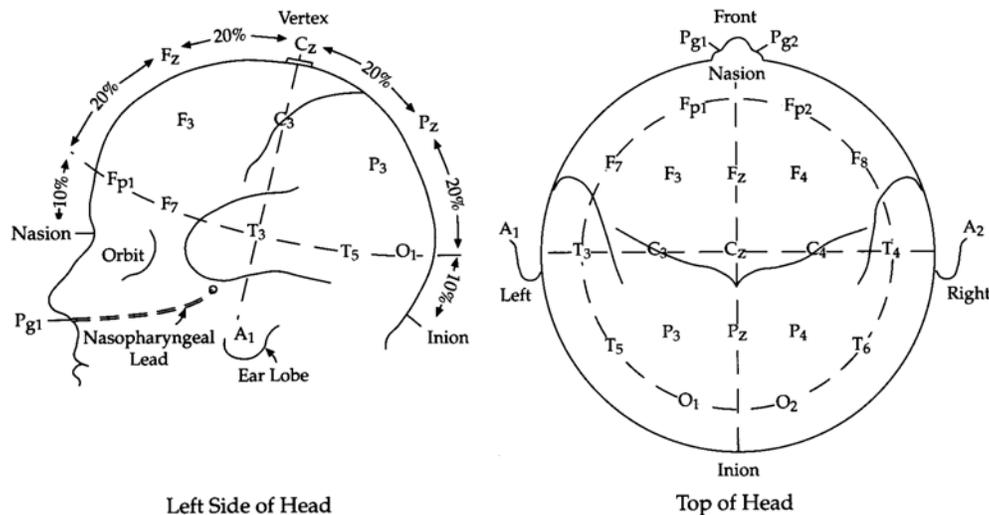


Figure 1: International 10-20 System of Electrode Placement

### Potential of Neurofeedback in Sport Psychology

Neurofeedback provides us with opportunities for both enhancing intellectual and sports performance without the use of performance enhancing drugs. There are several areas in which neurofeedback holds particular promise in sports, including enhancement of concentration and attention, reduction of anxiety, improving control over emotions (e.g., anger), for overcoming effects from mild head injuries and concussions, and for improving physical balance.

Different sports place different demands on the brain. Increasingly sophisticated research has begun delineating brainwave patterns associated with various types of peak performance. In such cases this provides us with important data that may guide the use of neurofeedback training to promote peak performance. One example will be provided. In the area of marksmanship, Haufler, Spalding, Santa Maria, and Hatfield (2000) found that during aiming, when marksmen were compared with novice shooters, marksmen exhibited less activation (increased alpha with less beta and gamma EEG activity) at all electrode sites on the head. The most pronounced differences were in the left central-

temporal-parietal areas. In relation to findings regarding anxiety and verbal processing, it is interesting that there have been reports of elevated left temporal alpha power, as will be reviewed shortly, in marksmen during response preparation. This has been interpreted to indicate the suppression of verbal-analytic processes. However, lower-order motor processes had not been excluded as a possible explanation, and, therefore, Kerick, McDowell, Hung, Santa Maria, Spalding, and Hatfield (2001) examined event-related alpha power (11-13 Hz) at temporal and central electrode sites (T3, T4, C3, C4) in eight skilled marksmen during shooting and during two control tasks varying in perceptual-motor complexity. Over an 8 second period preceding the trigger pull, the marksmen exhibited higher power and slope at T3 (the left temporal area) than at all other sites during shooting compared with the control conditions. These differences were not found in central areas (at C3 and C4), which means that these temporal findings cannot be primarily accounted for by “lower-order” motor processes.

Hatfield, Landers and Ray (1984) discovered that alpha power progressively increased in the left temporal area during the last 7.5 seconds of aiming, while there was no change in the right temporal area. These results are congruent with other research in the sport psychology literature that have shown less left hemisphere activation (more left hemisphere alpha power) in the preparatory period before golf putting (Crews and Landers, 1993) and archery (Landers, Han, Salazar, Petruzzello, Kubitz, & Gannon, 1994; Salazar, Landers, Petruzzello, & Han 1990). In archery, Landers et al. (1991) found that alpha synchrony neurofeedback training at T3 during aiming significantly increased performance in pre-elite archers compared with a group trained to increase alpha at T4 (right temporal area), which resulted in a decline in performance. In a longitudinal study over 14 weeks of archery training, Landers et al. (1994) discovered that left temporal alpha power increased and correlated with improved performance.

In contrast to neurofeedback training to increase alpha and quiet the mind in marksmanship or putting, athletes in some sports may need training to decrease alpha and theta activity in different areas of the brain, while increasing beta activity to produce an entirely different kind of concentration or arousal. The research by Landers et al. (1994) demonstrates that if the wrong type of neurofeedback training were done, it could also decrease performance. Thus this limited amount of research informs us that simplistic

types of neurofeedback training—a sort of one-size-fits-all approach—are unlikely to be very effective when applied to peak performance training across a variety of different sports. In addition to different demands being placed on the brain by different kinds of sports activities, the brain functioning of individual athletes also varies due to the influence of genetics (e.g., with ADD/ADHD) as well as variables such as head injuries (e.g., Collie, Makdissi, Maruff, Bennell, & McCrory, 2006; Killam, Cautin, & Santucci, 2005). For instance, there is some evidence that soccer players who do a lot of headers may experience EEG and neurologic changes (Tysvaer, Stroll, & Bachen, 1989) and have neuropsychological deficits (Rutherford, Stephens, Potter, & Fernie, 2005). Thus, not all brains need the same kind of training.

### **Neurofeedback to Enhance Physical Balance**

Another area where neurofeedback may hold potential for improving athletic performance is in facilitating greater physical balance. Consider the benefits that improvements in balance might have for enhancing performance in gymnastics, skiing, ice skating, hockey, skateboarding, snowboarding, ballet, and possibly also in tennis, martial arts, basketball, baseball, and football.

In the first publication on using neurofeedback to improve balance, the author (Hammond, 2005) reported on the successful treatment of balance problems in 4 clinical patients utilizing a specific protocol. Two patients, one 32 years old and another 50 years old, had experienced balance problems subsequent to mild head injuries, one from a whiplash and the other from mild head injuries in skiing and hiking. Two other patients (ages 45 and 46) had developed balance problems after having strokes. Within an average of 8-10 sessions there were very significant improvements in balance in all cases. These improvements were measured with a self-administered balance test wherein the patient stands his feet together, arms extended out to the sides, and then eyes closed walks heel-to-toe, heel-to-toe, afterwards rating the degree of balance on a 100 mm visual analogue scale.

The protocol consists of placing two electrodes on the back of the head, directly below electrode sites O1 and O2, at the top edge of the inion ridge. A ground electrode is placed on one earlobe. The neurofeedback protocol utilizes what is called a bipolar montage (meaning that both active electrodes are on the head, rather than having a

reference electrode on the other earlobe). The person is trained to inhibit 4-7 Hz while very mildly reinforcing 15-18 Hz activity. The EEG amplitudes are very small at this location in comparison with other places on the scalp, and the thresholds for reinforcement are adjusted accordingly so that the person is receiving ample reinforcement. Training sessions last for 30 minutes.

Since the initial publication there have been a variety of other clinical cases where this protocol has proven rapid and effective. These cases have included a 6 year old boy who received a moderate traumatic brain injury at the age of 1. Whereas prior to treatment he tended to trip over his own feet when simply walking a few steps and he was unable to run in a coordinated fashion, after his first 3 neurofeedback sessions utilizing this protocol he began running almost normally. Other more recent cases have included individuals with balance problems following mild head injuries and an 8 year old boy with developmental delays and severe ADHD. A physical therapist had been working with this boy in regular sessions for 2 years and yet he was still unable to ride a two-wheel bicycle more than 1-3 feet without falling over. After only 4 sessions with the balance protocol he began, to everyone's amazement, riding his bicycle more than 100 feet. In follow-ups several months later he had maintained his gains and was riding his bicycle effortlessly.

Whereas neurofeedback for conditions such as ADD/ADHD commonly involve 40-50 treatment sessions, neurofeedback to improve balance has usually consisted of only 8-10 sessions. Patients with balance problems can usually discern a difference in their balance after 1-2 sessions. The author used this protocol for several sessions with a member of the U.S. Olympic Ski Team in the hopes of increasing balance, but has not had the opportunity to use it further for peak performance training. Therefore, although this neurofeedback protocol would seem to have potential in its application to athletic performance, at this point there are no controlled studies with long term follow-ups that have been conducted.

### **Conclusion**

Sport psychologists will find that neurofeedback is a cutting-edge technology that holds potential for improving concentration and attention, lowering anxiety and disruptive mental chatter, and in assisting in the rehabilitation of effects from concussions

and mild head injuries. The author's experiences in treating patients with serious balance problems and observing their rapid improvements provides encouraging evidence for the potential neurofeedback to enhance physical balance in sports such as gymnastics, skiing, ice skating, hockey, skateboarding, and snowboarding. The rapid effects of this balance protocol make it particularly appealing. It is hoped that sport psychologists will experiment with applying this protocol with athletes and that controlled research will be conducted. Individuals wishing to learn more about neurofeedback can consult the International Society for Neuronal Regulation ([www.isnr.org](http://www.isnr.org)), the Association for Applied Psychophysiology and Biofeedback ([www.aapb.org](http://www.aapb.org)), and the American Board of Sport Psychology ([www.americanboardofsportpsychology.org](http://www.americanboardofsportpsychology.org)).

### References

- Collie, A., Makdissi, M., Maruff, P., Bennell, K., & McCrory, P. (2006). Cognition in the days following concussion: comparison of symptomatic versus asymptomatic athletes. *Journal of Neurological & Neurosurgical Psychiatry*, 77(2), 241-245.
- Crews, D. J., & Landers, D. M. (1993). Electroencephalographic measures of attentional patterns prior to the golf putt. *Medical Science & Sports Exercise*, 25(1), 116-126.
- Demos, J. (2004). *Getting Started in Neurofeedback*. New York: W. W. Norton.
- Egner, t., & Gruzelier, J. H. (2003). Ecological validity of neurofeedback: modulation of slow wave EEG enhances musical performance. *NeuroReport*, 14(9), 1221-1224.
- Hammond, D. C. (2005a). Neurofeedback with anxiety and affective disorders. *Child & Adolescent Psychiatric Clinics of North America*, 14(1), 105-123.
- Hammond, D. C. (2005b). Neurofeedback to improve physical balance, incontinence, and swallowing. *Journal of Neurotherapy*, 9(1), 27-36.
- Hatfield, D. B., Landers, D. M., & Ray, W. J. (1984). Cognitive processes during self-paced motor performance: An electroencephalographic profile of skilled marksmen. *Journal of Sports Psychology*, 6, 42-59.
- Hatfield, D. B., Landers, D. M., & Ray, W. J. (1987). Cardiovascular-CNS interactions during a self-paced intentional attentive state: Elite marksmanship performance. *Psychophysiology*, 24(5), 542-549.

- Haufler, A. J., Spalding, T. W., Santa Maria, D. L., & Hatfield, B. D. (2000). Neurocognitive activity during a self-paced visuospatial task: Comparative EEG profiles in marksmen and novice shooters. *Biological Psychology*, *53*, 131-160.
- Joseph, R. (1996). *Neuropsychiatry, Neuropsychology, and Clinical Neuroscience* (Fourth Edition). St. Louis: Mosby.
- Kerick, S. E., McDowell, K., Hung, T. M., Santa Maria, D. L., Spalding, T. W., & Hatfield, B. D. (2001). The role of the left temporal region during the cognitive motor demands of shooting in skilled marksmen. *Biological Psychology*, *58*(3), 263-277.
- Killam, C., Cautin, R. L., & Santucci, A. C. (2005). Assessing the enduring residual neuropsychological effects of head trauma in college athletes who participate in contact sports. *Archives of Clinical Neuropsychology*, *20*(5), 599-611.
- Landers, D. M. (1991). Optimizing individual performance. Chapter in D. Druckman & R. A. Bjork (Eds.), *In the Mind's Eye: Enhancing Human Performance*. Washington, D.C.: National Academy Press, pp. 193-246.
- Landers, D. M., Han, M., Salazar, W., Petruzzello, S. J., Kubitz, K. A., & Gannon, T. L. (1994). Effect of learning on electroencephalographic and electrocardiographic patterns in novice archers. *International Journal of Sports Psychology*, *22*, 56-71.
- Monastra, V. J. (2005). Electroencephalographic biofeedback (neurotherapy) as a treatment for attention deficit hyperactivity disorder: Rationale and empirical foundation. *Child & Adolescent Psychiatric Clinics of North America*, *14*(1), 55-82.
- Moore, N. C. (2000). A review of EEG biofeedback treatment of anxiety disorders. *Clinical Electroencephalography*, *31*(1), 1-6.
- Raymond, J., Sajid, I., Parkinson, L. A., & Gruzelier, J. H. (2005). Biofeedback and dance performance: a preliminary investigation. *Applied Psychophysiology & Biofeedback*, *30*(1), 65-74.
- Rutherford, A., Stephens, R., Potter, D., & Fernie, G. (2005). *Journal of Experimental Neuropsychology*, *27*(3), 299-319.
- Salazar, W., Landers, D. M., Petruzzello, S. J., & Han, M. (1990). Hemispheric asymmetry, cardiac response, and performance in elite archers. *Research Quarterly in Exercise & Sport*, *61*(4), 351-359.
- Sterman, M. B. (2000). Basic concepts and clinical findings in the treatment of seizure disorders with EEG operant conditioning. *Clinical Electroencephalography*, *31*(1), 45-55.

- Thompson, M., & Thompson, L. (2003). *The Neurofeedback Book*. Wheat Ridge, CO: Association for Applied Psychophysiology & Biofeedback.
- Tranel, D. (2002). Functional neuroanatomy. Chapter in S. C. Yudofsky & R. E. Hales (Eds), *Textbook of Neuropsychiatry & Clinical Neurosciences* (4<sup>th</sup> edition). Washington, D.C.: American Psychiatric Association Press, pp. 71-112.
- Tysvaer, A. T., Stroll, O. V., & Bachen, I. (1989). Soccer injuries to the brain: A neurologic and electroencephalographic study of former players. *Acta Neurologica Scandinavia*, 80, 151-156.