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# The human brain and sports performances: a coaches' perspective

Henk Kraaijenhof *, Amstelveen, Holland



Although the functioning of the human brain during exercise and training has been the subject of research since 1950 (1), recent developments in technologies and electronics make it possible to investigate this most complex and interesting human performance organ.

For practical use in sports the following fields of brain functions will be described:

- brain-states, as measured by EEG
- biofeedback
- hemispheric lateralization and its implications for sports

## Brain-states

Research of brain-activity during exercise and training has been perfomed since 1950 (1).

Most research in this field has been done by EEG-measurements.

EEG measures the electric activity of the brain by sensitive electrodes placed on the scalp. According to the International Federation of Societies for Electroencephalograpy and Clinical Neurophysiology, the most important brain-waves can be distinguished:

| *Wave* | *Frequency* | *State* |
|---|---|---|
| Beta waves | 13-35 Hz | alert, awake |
| Alpha waves | 8-13 Hz | eyes closed |
| Theta waves | 4-8 Hz | twilight zone between waking and sleeping |
| Delta waves | 0.5-4 Hz | deep sleep |

The level of arousal of the brain is related to the frequency of the brain-waves, the higher the frequency, the higher the level of arousal.

The brain-activity is not homogenuous over the scalp, some parts may display another frequency than other parts, depending on the activity of the underlying brain-lobes.

One of the main problems for athletes is the control of their arousal before important competitions.

The coach wants to prevent the athlete from being too nervous or too "cool".

A concept is the description of three pre-start conditions (2):

1 - optimum startcondition

2 - startfever (arousal too high)

3 - startapathy (arousal too low, main a sign of inhibition-processes)

These conditions coincide with the classical concept of the Yerkes-Dodson law that shows an optimum relationship between arousal and performance.

Although this concept has been modified, it has still practical validity and still shows there is an optimum level of arousal (3,4).

Especially in the former Soviet-Union many attempts have been made to measure arousal in precompetition situations e.g. by measuring galvanic skin response of skin resistance and other parameters. These measurements were used to study the optimum levels of arousal and to find ways to optimize them, in order to reach a state of maximum performance (5).

Modern equipment not only makes it possible to measure brain-waves, but also to process that information and give a real-time visual display as feedback or feedback by means of acoustic information like tones or music (6).

In this way the athlete learns to control his or her own brain activity, which is helpful in adjusting to the right level of arousal.

In some equipment multi-modal input can be processed like EEG, EMG (electromyography), skin temperature and skin resistance, all simultaneously.

EEG-biofeedback has been used and shown useful in many clinical settings (7, 8).

But EEG-measurements can also be helpful in sports, to monitor changes in brain activity during exercise (1, 9, 10, 11) e.g. to prevent a state of overtraining (1), or to be transformed into feedback-information (12).

## Biofeedback

Biofeedback can be used to monitor and to control the athlete's internal processes.

Already succesfully used in clinical settings, biofeedback can also be used to control and optimize level of the arousal in the preparation of athletes (13, 14).

A wellknown application of biofeedback equipment is the polygraph or the lie detector where biofeedback equipment is used to monitor the changes in arousal upon verbal questioning.

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The difference with biofeedback is that in case of the polygraph not the subject, but the interrogator gets the information about the physiological changes.

In sports the widespread use of running, cycling or rowing with a heart rate monitor is nothing else than a biofeedback method, assuring an optimum level of training-intensity.

The input can be:
- heartrate
- skin resistance of GSR
- EMG
- EEG
- temperature

The output can be:

Acoustic:
- beeps from a heart rate monitor
- one's favorite CD or piece of music from a multimedia-computer.

Visual: a computer monitor can display the feedback in the form of:
- line or bargraphs
- numbers
- dials
- changes of colours
- changes of shapes
- playing of videofilms

A practical example is when one wants to teach the athlete to generate alpha-state (8-13 Hz).

The alpha and also the theta state are optimal for the processing of information such as visualizations of movements like in competitions or for mental programming.

One can define the alpha state as such and when the athlete generates more than 7 Hz, but less than 13 Hz let him or her listen to his favourite piece of music or natural sounds like gentle rainfall, rushing brooks or waves on a beach. When these programmed sounds appear the athlete knows he or she reached the demanded alpha state. Quiet music or natural sounds also increase the presence of the alpha state.

When the athlete is in alpha state, he hears the sounds, produced by his own brainwaves and this can be combined with verbal instructions e.g. visualizations of competitions.

In case of alpha state one choses acoustic feedback, because alpha state is easier reached with the eyes closed, thus making visual feeedback less appropiate.

Alpha feedback is the most frequently used and investigated form of EEG biofeedback (15, 16).

*Summarizing:* (EEG-) biofeedback is in the practice of elite athletes a valuable tool for measuring, monitoring and controlling athlete's mental conditions.

## Hemispheric lateralization

The human cerebrum is divided into two hemispheres, the left hemisphere and the right hemisphere.

These two brain halves are connected by the corpus callosum, through which information passes from one hemisphere to another.

These hemispheres show asymmetry, both anatomical and functional.

The anatomical difference is related to the asymmetry in function.

Most humans show a left or right preference for handedness, footedness, and eyedness, which is easy to notice and to measure. This is mainly a senso-motor preference.

It is less obvious that more functions are completely or partially related to one of the two hemispheres.

An example is the location of the Broca and Wernicke areas, important for speaking and understanding the spoken language, in most right handed people situated in the left side of the brain.

From research by Roger Sperry, Norman Gschwind, John Eccles, Stuart Dimond, Jerre Levy, Doreen Kimura, Rhawn Joseph and many others we know that for many specific human abilities we use only certain parts of the brain, mainly located on the left side or the right side, dependent on the function (17, 18, 19, 20, 21, 22, 23).

These results are established by EEG-measurements, brain blood flow measurements, neuropsychological test in "split-brain" patients or the Wada-test, in which the left or the right part of the brain is "paralyzed" by an anaesthetic agent and tested what functions are influenced.

The general tendency of these investigations is that the two brain halves seem to specialize in certain functions for which they are better equiped or programmed than the other half.

A few different funcions of each hemispheres are summarized in Table 1.

Table 1

| LEFT HEMISPHERE | RIGHT HEMISPHERE |
|---|---|
| - communication through language | - communication through body language and facial expression |
| - serial or digital information-processing | - parallel or analog information-processing |
| - logical and rational thinking | - creative and emotional thinking |
| - thinking in words | - thinking in images |
| - arithmetical thinking | - visual-spatial thinking |
| - analytical thinking | - holistic thinking |
| - mathematical and language skills | - motor rhythmical-musical social skills and creativity |

The distinction between left and right halves of the brain may not be so clearcut as shown above.

To avoid discussion about the exact anatomical position of a certain functional ability, it is better to use the expression left brain **mode** and right brain **mode** to refer to the functions summed up in table 1.

The practical relevance of this distinction between left and right brain modes is that it helps one to understand important issues like motor learning, coordination, coach-athlete-communication, arousal and mental preparation.

One of the first practical applications of this distinction between left brain mode and right brain mode can be found in the book "The inner game of tennis" where W. Timothy Gallway explained the difference of the Self 1, also called the "teller" (left brain mode) and the Self 2, also called the "doer" (right brain mode) (24).

He explained the phenomenon of negative interference of verbal thinking with holistic motor-pattern functioning, in the case of playing tennis.

In recent years more appeared about these brain modes and sports performances, mainly in the field of motor learning and functioning (25, 26, 27, 28, 29, 30).

In general these papers confirm the distinction between the left and right brain modes and the importance of different approaches in teaching motor skills to subjects with left or right brain mode dominance.

Gallway's finding of the negative influence of verbalization on motor patterns has been tested and the phenomenon of verbal-motor disruption has been confirmed (28).

In general, it seems that a right brain dominant mode is better adapted for motor learning and performing than the left brain mode. Hence the importance of visual information for teaching and correcting motor patterns at least for subjects with a dominant right brain mode of functioning.

For subjects with a dominant left brain mode of functioning verbal instructions might be superior in effectiveness, while in non-dominant-hemisphere subjects the combination of verbal and visual instruction seems to be the optimum method for learning and improving motor learning.

An interesting aspect is the biological origin of the hemisphere differentiation and the function of the right brain mode for sports performances.

Research shows that the output of testosteron by the mother during pregnancy inhibits the development of the left hemisphere and in this way relatively promotes a more optimal development of the right hemisphere (31, 32, 33).

Also in later stages of life a positive relationship between serum testosterone level and the learning of motor skills continues to exist (34, 35).

This could possibly add another performance-enhancing factor for the use of anabolic steroids and testosterone on sports performances. The effects of testosterone on the human brain and therefore on motor functioning could as well be the key to the performance-enhancing capacity of this doping-agent.

The latest research in this field is the discovery of the difference in where and how males or females process language in their brain (36, 37).

This is once more a piece of evidence that the female brain is differently wired from the male brain.

For scientists this might be surprising, for coaches it hardly is.

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