

# The Effects of EEG Neurofeedback Training on the Behavioral Complaints of Soccer Athletes

## A Case Study

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**Abstract:** Several studies supports that neurofeedback training enhances human skills to control the predominance of cerebral activity by specific frequencies. This training modality was related to efficient applications in clinical use, education, businesses and sports. Behavioral changes were found after the neurofeedback training in various circumstances, eliciting more functionality and accuracy, but no studies were found considering the effects of the neurofeedback at the behavioral and psychological complaints of young soccer athletes. The aim of this work was to evaluate the effects of a sensorimotor rhythm training program and its applicability for the sport psychology practice. Five soccer athletes referred to the Sport Psychology department were systematically trained to increase the sensorimotor rhythm amplitude and then, were interdisciplinary monitored by coaches, physical trainers, medical and psychological services. As results, 4 from 5 athletes were considered remitted from the initial dysfunctional complaints. These changes were found such in technical, tactical, physical and psychological aspects, and they varied between athletes and personal demands. As conclusions, the present work pointed evidences that the neurofeedback training program can be an important technology to support the practices of the sport psychology, as to enhance functional behaviors and to promote mental health for developing soccer athletes.

## 1 INTRODUCTION

The neurofeedback is a training technique based on the feedback of the physiological signal to the brain, which enables people to alter and control their brain waves and exercise the own self-regulatory mechanisms (Larsen and Sherlin, 2013). Acting as a kind of operant conditioning, the neurofeedback applications emerged in health promotion, education and in centers of human performance, as the sports clubs (Serman, 2000).

The neurofeedback has been traditionally made by the electroencephalographic (EEG) or hemoencephalographic (HEG) signals (Hammond, 2011), although some researchers has proved that the functional magnetic resonance imaging (fMRI) can also used as an efficient neurofeedback modality (Weiskopf et al., 2004). Focusing on the EEG Neurofeedback, also named EEG Biofeedback, it

has been already proved as a safe and efficient method for training the brain to regulate mental states and related behaviors, with utilities in peak performance and in clinical demands (Larsen and Sherlin, 2013). There is a broad range of beneficial effects of EEG neurofeedback training on athlete's performance proved in several studies and different modalities (Hammond, 2007; Dupee and Werthner, 2011; Wilson and Peper, 2011; Perry et al., 2011; Wilson, Peper and Moss, 2006; Nan et al., 2014).

Regarding soccer modality, Wilson and colleagues (2006) reported a case study with the Italian players during the 2006 World cup. They use a space referred as the "Mind Room", which biofeedback modalities comprised the feedback of such brainwaves (neurofeedback), cardiovascular and electrodermal responses, while the soccer players viewed short video clips of successful and unsuccessful performances. The main purpose of

this study was training psychological skills to help them to relax and control physiological reactions under pressure situations. The success of the "Mind Room" program may have reflected in the Italian world title.

Unfortunately, although the EEG biofeedback has gained prominence in the international sports centers, it has little attention in Brazilian sport science over the last decades. The emotional dysfunction of Brazilian soccer players during 2014 World Cup and also 2015 American Cup may reflect the negligence or a old-fashioned and poorly psychological assistance. The fact is that Zaichkowsky (2012) pointed some limits to introduce this kind of assistance, as the fact that the hardware and technology were expensive, and that the sport practitioners and managers do not know the theory and application of this technology. Although the Brazilian difficulties, this case study reports a positive experience with young Brazilians soccer players, referred to the Sport Psychology department.

Among diverse EEG Neurofeedback training protocols, the Sensorimotor Rhythm (SMR) can be done enhancing of 12–15 Hz band while inhibiting outer lying bands in the EEG spectrum (Vernon et al., 2003). The SMR training has been related to several cognitive gains (Vernon et al., 2003; Nabavi et al., 2014; Doppelmayr and Weber, 2011). These beneficial effects were found in several studies, showing improvements on reaction times (Nabavi et al., 2014), affective processes (Gruzelier, 2014a), visuospatial abilities and creativity (Doppelmayr and Weber, 2011). Also, SMR learning indices are positively associated with the reduction in commission errors in sustained attention tasks (Egner and Gruzelier, 2001) and with memory consolidation (Schabus et al., 2014). In Sports, this training protocol was also proved as an effective method (Del Percio et al., 2009; Brown et al., 2012; Perry, Shaw and Zaichkowsky, 2011).

Looking to these SMR related effects on mood, behavior and cognition, the present study analyze the effects of SMR training on the complaints of 5 soccer athletes and its applicability in soccer demands. The aim of this work is to evaluate behavioral changes after a sensorimotor rhythm training program (enhancing 12-15 Hz) and its applicability in soccer demands.

## 2 METHODS

The research can be considered as a case study, with

exploratory and descriptive methods. This methodology approach comprehends analysis under the epistemological view of subjectivism interpretative and phenomenological and was not designed to consider potential placebo effects, neither to promote widespread conclusions (García-Celay and León, 2007; Yin, 2013). However, the case study methods are quite relevant for development the sport and health sciences, enabling the sharing of personal experiences and contributing for the dissemination of knowledge, debates and reviews of strategies, diagnoses, interventions and learning. In psychology, this method can be considered relevant and a very useful investigative tool (Hardy et al., 2001; García-Celay and León, 2007; Yin, 2013).

### 2.1 Participants

The study involved 5 young soccer athletes (15-19 years old), affiliated in a traditional and professional soccer club at Rio de Janeiro, Brazil. All of them were referred to the Sport Psychology Department with behavioral and psychological complaints. To ensure their privacy, participants will be referenced with representative numbers. The respective tactical functions were: athlete 1, center defender; athlete 2, midfield; athlete 3, a center forward; athlete 4, goalkeeper; athlete 5, midfield. Involved either five institutional sectors linked to the soccer department: physical therapy (2 professionals), psychology (3 professionals), physical education (3 professionals) and the coach areas (2 professionals).

### 2.2 Apparatus and Procedure

The EEG biofeedback training of the sensorimotor rhythm was conducted according Vernon and colleagues (2003) periodicity: over a period of 4 weeks, with each participant receiving two training sessions per-week. Each session contained four 5-min periods. The training program was administered using the ProComp system (Thought Technology Ltd) and the Biograph Plus 2.1 software. Signal was acquired at 160 Hz, converted and band filtered to extract delta (0–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), SMR (12–15 Hz) and beta (18–22 Hz) components. The active electrode was recorded from CZ for all training session, with reference placed on the left and ground electrode on the right earlobes respectively. Impedance levels were monitored by visual inspection and the artifact rejection thresholds were set individually, suspending feedback when eye-movements or other muscle activity caused

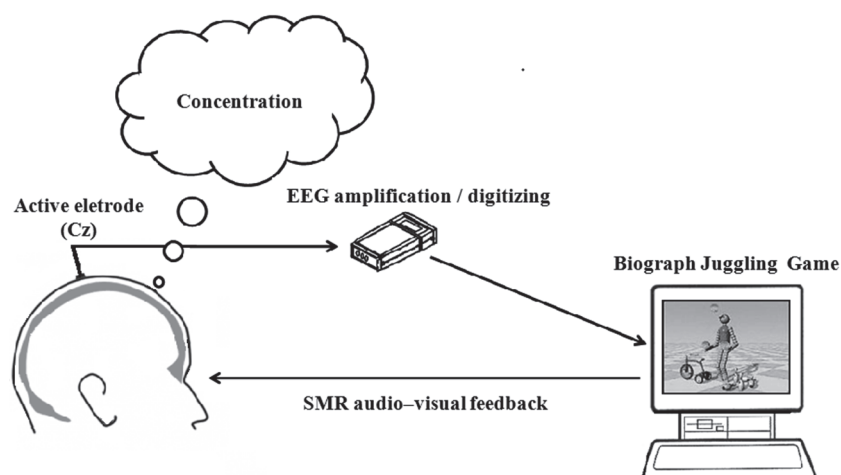


Figure 1: Operating dynamics of the neurofeedback sessions: signals were collected from Cz, amplified and a real-time feedback was displayed on the computer.

gross EEG fluctuations.

The SMR (12–15 Hz) were fed back using an audio–visual online feedback loop in the form of a bar, with the amplitude of the SMR frequency varying in the size of the bar. The participants’ task was to increase the size of the training frequency bar and, on meeting this goal, a clown performed juggling with music (figure 1). For training, the athletes remained seated and with his hands resting on his legs, they were instructed to suppress any thought and to focusing in the game.

### 2.3 Analysis

Analysis were made considering the reports of the five institutional sectors. The single variable investigated was the multidisciplinary concordance about the initial dysfunctions, considering the incidence of behavioral complaints such as physical symptoms, technical questions and tactical execution. The analysis also considered the methods and techniques used by each sector because they are content of the institutional reports. Psychological assessments were made using a combination of techniques, which comprised behavioral observations (during trainings and matches), individual interviews and multidisciplinary meetings. The Interviews investigated recent life experiences at psychosocial, emotional, cognitive and behavioral spheres. The physical assessment was made through clinical interviews made by doctors and physical therapists asking about physical state, injuries and complaints related to the athletes. The technical and tactical assessments were made through extensive and systematic daily training

observations for the coach and physical trainers. The training sessions observed varied according the day of the week, and may comprise soccer game trainings, technical or physical sessions. In addition, some external events were also considered as non-institutional indicators of behavioral changes and were described in results.

The criteria for concluding if the initial complaints changed or not, required unanimous concordance about the absence of dysfunctional states. The analysis considered reports made before, and after 4 months to the end of the 4-week neurofeedback training period.

## 3 RESULTS

All participants were continuously monitored by the multidisciplinary sectors. During the neurofeedback sessions, all of the athletes demonstrated enhancing skills to generate, maintain and to manage the desired SMR wave pattern.

The results of multidisciplinary evaluation are below specified for each athlete and summarized in table 1. The analysis of this case study showed that remission of the initial complaints was attributed to 80% of the sample (4 from 5 athletes).

### 3.1 Athlete 1

When he started the neurofeedback practices, he was training away for the remaining athletes. The coaching staff and the soccer coordination did not believe in his capacity to stay in the team, because serious technical and tactical errors was observed,

Table 1: Results of initial multidisciplinary assessment, considering psychological, physical, technical and tactical aspects.

Athletes	Psychological aspects	Physical aspects	Technical and tactical aspects
Athlete 1	Emotional instability; sadness; anxiety; anger; nonconformity thoughts; impairments; unfocused; slow In taking decisions.		Low technical level; difficulties in tactical execution; alternate Condition; doing separate trainings; expectation to be sent out off the team
Athlete 2	High anxiety, recurrent insomnia	Recurrent injuries; slow physical recovery	Titular condition; regular performance
Athlete 3	Impulsiveness; recurrent anger; inadequate relationships with technical committee; indiscipline episodes		Alternate condition; difficulties In Tactical Execution
Athlete 4	Inadequate interpersonal relationships; psychological resistance; recurrent delays, indiscipline, recurrent anger episodes		Performance Instability
Athlete 5	Anxiety, impulsivity and restlessness	Motor restlessness	Diverse Fouls And Misconduct; Constant Punishments With Yellow And Red Cards.

detected during the interdisciplinary observation during soccer trainings and official matches. When asked about his performance, the athlete reported perceptions of uncertainty and oscillations. It was also observed that the temporal judgment was affected, because sometimes his timing accuracy failed, anticipating movements or slowing reactions. He was characterized as a player with low technical level and with difficult performing of tactical instructions when requested by the team coach. After two weeks (four training sessions with neurofeedback), he was integrated into the group again, and selected to participate in Switzerland on a sub-20 international competition supported by the *Fédération Internationale de Football Association* (FIFA). After more two weeks, during the period when the team remained outside of the country, the ATHLETE 1 demonstrated technical improvements from the point of view of the team's coach. As an external indicator, the full recovery of the initial performance complaints were proven by a prize awarded at the FIFA competition, being considered one of the best players of the event.

### 3.2 Athlete 2

He self-reported the remission of insomnia crises and less anxiety levels. The physiotherapy section detected less physical complaints. The psychology sector identified that the trainer praised his performance more times. As external indicators, he was considered his convocation to Brazilian sub-20 soccer selection, two months after the end of the Neurofeedback program.

### 3.3 Athlete 3

Before the neurofeedback practices, the athlete 3 was dissatisfied with the coach and with the

reserve situation. For the Psychology sector, the athlete' dissatisfaction influenced his behavior during several soccer training sessions, giving inappropriate tactical conducts and influencing the quality of your relationship with some members of the coaching staff and with the institution itself. He was referred to the Psychology sector by the coach after demonstrate persistent indiscipline in relation to the coaching staff and other employees of the institution. His rebel behavior was behaviorally manifested on the pitch in the refusal to obey simple tactical instructions requested by the coach. Initial behavioral changes were found after few weeks of completing the neurofeedback program. As change indicators, the absolute starter can be considered and also the more flexible relations with coaches' instructions and the enhancement of converted goals. During the follow-up period were not recorded indiscipline complaints nor relationship problems. Two external indicators of changes in the initial complaints must be considered: the artillery of the principal soccer tournament to the category and also, the convocation for Brazilian Sub-17 soccer selection by the Brazilian Football Confederation.

### 3.4 Athlete 4

Although being in technical progress, even before beginning the neurofeedback training, the coaching staff increasingly praises to this goalkeeper. The only changes recorded after the start of activities with neurofeedback was the improvement in the relationship with the psychology service (after a history of resistance) and also with the goalkeeping coach. Were also identified delays reductions for the training sessions, which were common before the Neurofeedback program.

Table 2: Results of the multidisciplinary assessment after the SMR Neurofeedback training and the respective qualitative condition of the initial complaints.

<b>Athlete</b>	<b>Overall post SMR assessment</b>	<b>Qualitative condition of the initial complaints</b>
Athlete 1	Satisfactory performance; emotional stability; greater accuracy and decision making; more ability to focusing; titular condition; won a prize at a international competition sponsored by FIFA	Remission of the initial complaints. The athlete's overall condition was qualitatively different after the neurofeedback program
Athlete 2	Insomnia remission; lower levels of anxiety; injuries decreases; more coach's praises; convocation for Brazilian Sub-17 team	Remission of the initial complaints. The athlete's overall condition was qualitatively different after the neurofeedback program
Athlete 3	Higher emotional control; more functional behaviors; titular condition; Artillery in the state championship; convocation for Brazilian Sub-17 team; none indiscipline episode was reported	Remission of the initial complaints. The athlete's overall condition was qualitatively different after the neurofeedback program
Athlete 4	Good relationship with the team work; lower psychological resistance; reducing delays; none indiscipline episode was reported	Remission of the initial complaints. The athlete's overall condition was qualitatively different after the neurofeedback program
Athlete 5	Anxiety; restlessness; impatience; no red cards were attributed but still received some yellow cards	No changes were found for the initial complaints. The athlete's overall condition was not qualitatively different

### 3.5 Athlete 5

For the athlete 5, the main complaint was the excessive number of expulsions and of yellow cards obtained during championship. Analyzing the reasons for the dangerous faults, it was identified that the athlete not expected the best time to steal the ball from the opponent, he was impulsive and anticipated his movement with unnecessary faulty entries. In addition, during psychological sessions, psychomotor agitation were found and others evidences about anxiety. After the neurofeedback program, the staff doesn't found significant behavioral changes, he continued to make unnecessary fouls and earned many yellow cards, even without being outcasted after neurofeedback program ended.

On a general view, the initial complaints varied between athletes, but we can summarize the presented questions as dysfunctional behaviors, emotional instability and with some performance problems (technical and/or tactical aspects).

The results for each athlete, pre and post neurofeedback training program were below summarized and discriminated in table 2. In common, the athletes enhanced cognitive skills, emotional control and the soccer performance (in tactical and/or technical aspects), excepting the athlete 5.

## 4 DISCUSSION

The purpose of this paper was to disclose the

neuroscientific contributions for high performance sports and also during the athlete development. The neurofeedback training can be an important tool to assist the other professional fields in a multidisciplinary way. Herein, ours results showed how this technology led to important qualitative changes in 4 from 5 soccer athletes referred to the Sport Psychology department.

Several indicators of the neurofeedback efficiency in high performance athletes were guided on quantitative analyzes which considered the subject's ability to maintain and generate the specific trained brain wave allied to behavioral measures in specific cognitive tests (Hammond, 2007; Dupee and Werthner, 2011; Wilson and Peper, 2011). However, critical issues considered that such scalp changes and quantitative cognitive perspectives might not reflect substantial changes in one's life (Vernon, 2005). According Maanen (1979), to verify the quality of a phenomenon is not necessary to consider implicit and accurate data related to such manifestation. In this way, the combination of systematic multidisciplinary assessments attested important changes for these athletes' professional and personal spheres, proving the relevance of the neurofeedback technological support.

Although Vernon and colleagues (2003) reported advances after 8 training sessions with SMR protocol, the behavioral changes in some of the athletes of this study, surprised coaches, researchers and the sport psychology team. According to Wilson and Peper (2011), the neurofeedback training with high level athletes have important differences when compared to the clinical use. One of them is the

athlete's learning ability: they would be able to conduct a more intensive transfer of learned skills to a real demand, which would be responsible to faster results when compared to clinical patients.

Our results were found in different spheres, with technical, tactical and psychological benefits reported. These results may be explained by the literature that proves a diverse range of SMR neurofeedback efficiency. The SMR neurofeedback training was already be related to beneficial effects in different cognitive functions (Vernon et al., 2003; Nabavi et al., 2014; Doppelmayer and Weber, 2011), emotion (Gruzelier, 2014a), accuracy (Egner and Gruzelier, 2001) and performance (Gruzelier, 2014b; Del Percio et al., 2009; Brown et al., 2012; Perry et al., 2011).

## 5 CONCLUSIONS

Using systematic and qualitative methods to analyze behavioral changes, the work clearly identified that behavioral patterns were changed after the SMR neurofeedback training, when compared to the initial complaints. As an applied study, this work helped to recover athletes who would be wasted or underused. Therefore, the data also reinforce that the neurofeedback is an important technology to support the soccer players formation, ensuring better results for the institution's main role. As conclusions, we suggest that the control of SMR frequency can be an interesting psychological training strategy for soccer athletes' development, being related to mental health and functional behavioral skills.

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