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ARTICLE

Effect of Sensory Motor Rhythm Neurofeedback on Psycho-physiological, Electro-encephalographic Measures and Performance of Archery Players

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Abstract
Neurofeedback is an effective tool in sports psychology to train athletes to enhance performance levels. Archery players are required to concentrate on accuracy during archery performances, which tends to be attained by a peak sensory motor rhythm of the electroencephalography component. The selected subjects of university level archery players have intervened with neurofeedback for four weeks. Measurements were taken to find the effect of neurofeedback training (NFT) on heart rate deceleration, pre-competition pleasure level, post-competition pleasure level, pre-competition arousal level, post-competition arousal level, performance level, precision, sensory motor rhthm (SMR)/ theta ratio and SMR epoch mean of archers during competition. Statistical analysis reveals that pre-competition pleasure level ($p< 0.05$), pre-competition arousal level ($p< 0.05$), post-competition arousal level ($p< 0.01$) and SMR/ theta ratio ($p< 0.05$) showed statistically significant changes [deleted after the effective twelve sessions of SMR neurofeedback training] in the experimental group but not the control group. After twelve sessions of NFT training the experimental group archers were able to regulate the psychological status and EEG components during archery performance. The result of the present study suggests that neurofeedback training improves the archery players' regularity in scoring by enhancing accurate arrow shoot attained by controlling and regulating psycho-physiological and electro-encephalographic measures.

Key Words: NFT (neurofeedback training) archery, Pleasure, Arousal, Heart rate, International Archery Federation (FITA), Precision, SMR (sensory motor rhythm).

Introduction
Archery requires the interaction of psychological factors (pleasure-arousal), physiological measures (heart rate and respiration rate) and motor performance. In the field of sports, arousal is one of the most important psychological

variables which influences the motor performance and, more importantly, precision (1). Neurofeedback is the efficient tool that regulates the psycho-physiological measures to enhance the performance of the player (2).

Neurofeedback with beta wave enhancement via instrumental learning to improve the task in cats stimulated research to find the effect of neurofeedback in humans (3). Recent work created a pathway to develop physical and cognitive performance via neurofeedback training in healthy individuals (4-6). Neurofeedback training (NFT) enhances performance levels in sports by manifestation of electroencephalograph (EEG) measure, physiological and psychological components (2). For example, neurofeedback on pre-elite archers has shown that feedback increased bandwidths and improved accuracy of arrow shot (7). The determined basic consideration in NFT with EEG components (alpha, sensory motor rhythm (SMR), theta, alpha/ theta & beta) and hemo-encephalography (HEG) to enhance golf sports performance has been illustrated in past relevant studies (8,9).

The regulation of EEG components influencing physiological measures thus provided the optimal mental status to enhance performance. The physiological measure considered in the athlete is heart rate (HR) and the psychological measures are pleasure-arousal levels. Heart rate was measured by using POLAR heart rate monitor along with pleasure-arousal, which was measured by Affect Grid in athletes.

On the other hand, neurofeedback training enhances overall performance of athletes, which promotes its definitive use (2). The enhancement of performance is multi-factorial, consisting of regulation of arousal, concentration and motivation, autonomic control and to incorporate these aspects simultaneously during competition (10,11,12).
The operant enhancement of the SMR (12-15 Hz) component is associated with a reduction in errors and progressive sensitivity of perception of a continuous performance task (CPT). A significant increase of beta1 frequency was related to enhancement of SMR (16). Moreover, audio-visual cues provide sufficient feedback to enlighten the sequence of the psycho-physiological state (17). The present study revealed that both audio and visual feedback were incorporated to strengthen the effect of neurofeedback training.

Many athletes fail to interoperate between psycho-physiological factors and motor performance measures during competition. Many studies have investigated the cognitive performance (3,7,17,18), but none have proved that regulation of psycho-physiological measures in sports performance can be improved. Systemic neurofeedback training aims to enhance or inhibit the particular component of EEG frequency to sustain the mental status of the athlete during the period of competition.
The purpose of the present study was to find out the effect of neurofeedback training on improvement of the archery performance and psycho-physiological variables for a particular interval. The expectation of our study was to derive an effective tool to regulate the psycho- physiological measures for optimal performance in archery players.

Materials and Methods

Twenty-four right-handed university level archery players, both male and female, were included by random sampling technique. They were divided into the Experimental group (12 archers, 8 male & 4 female) and the Control group (12 archers, 8 male & 4 female). Average age was 21.96 ± 1.601 years, with experience of 4.31 ± 1.081 years. The subjects signed informed consents according to the Institutional Ethics Committee Regulations Guru Nanak Dev University, Amritsar, India. Pre-post measurements of heart rate, pleasure-arousal level, precision, performance and baseline assessments of EEG were taken for both groups. None of the subjects had been introduced previously to neurofeedback training and none had any history of head injury. They were asked to refrain from any kind of mental training techniques or any meditation during the period of intervention. The research was conducted at the Sports Psychology Lab, Faculty of Sports Medicine & Physiotherapy and Outdoor Archery Field, in Guru Nanak Dev University, Amritsar, India.

The competition was set up to measure performance of two archery players at a distance of 70m (Olympic Round) by FITA regulations for both men and women (19). Archers were required to shoot 72 arrows, consisting of twelve rounds each ends with six arrow shots. During archery performance, heart rate measurement was obtained with the POLAR S410 Heart Rate Monitor. Subjects were asked to wear the chest belt device to monitor HR, which measured and averaged the value of HR for every five seconds. Later data was transferred to the computer and analyzed post performance.

Pleasure-Arousal level was measured by Affect Grid, which has 9×9 set squares ranging from one to nine horizontal and vertical directions for pleasure and arousal respectively (20). Before and after competition, subjects placed check mark in the squares of the Affect Grid as a response of mental status/ feelings. The pleasure score was taken as the number of the square checked, with squares numbered along the horizontal dimension, counting one to nine starting at the left. The arousal score was taken as the number of the square checked, with squares numbered along the vertical dimension, counting one to nine starting at the bottom.

Before and after performance, pleasure-arousal (Pre Competition Pleasure level= Pre-CPL, Post Competition Pleasure Level= Post-CPL, Pre Competition Arousal Level= Pre CAL, Post Competition Arousal Level= Post-CAL) was taken to analyze any neurofeedback training influence.

Procomp5 Infiniti by Thought Technology (Canada) was used to provide neurofeedback training to the experimental group. The experimental group of archers received SMR training for four weeks, three times in a week. A session of 20 minutes NFT was used without interruption and subjects were asked to do no meditation or any other neurotherapy.

Preparation of subjects was done prior to training sessions: skin on the scalp at Cz region and ear lobes were cleaned with NuPrep abrasive skin prepping gel followed by active electrodes filled with TEN 20-conductive gel. Subjects were seated comfortably in chairs with arm rests, and were allowed to relax for five minutes. After that time, active electrodes were placed at Cz, and reference electrodes were placed at both ear lobes. Sessions started with signal verification to check the encoder impedance followed by pre-assessment of baseline EEG. The instruction "keep the animation moving" was given to athletes to enhance low beta/ SMR (12-15 Hz) frequency at high mean value, meanwhile inhibiting the theta (4-7 Hz) along with high beta (22-26 Hz) frequency components throughout the sessions. Final sessions ended with post assessment of baseline EEG. Following an initial 30 seconds of training, auto-threshold levels of SMR were fixed by design of the protocol. The athlete received a 'ding' sound as a reward when able to enhance SMR and inhibit theta, high beta via keeping the animation moving continuously for one second. This training was a combination of audio-visual feedback which made training superimposed on EEG components of Low Beta/ SMR frequency.

Table 1. Paired 't' test results of Experimental and Control group archery players

Variables	Experimental Group		T value	Control Group		T value and p value.
	Pre	Post		Pre	Pots	
Heart Rate	116.08±9.96	113.75±7.35	2.310*	110.75±10.76	110.0±9.04	**0.534** NS
Pre-CPL	6.67±1.073	6.83±0.94	0.518 NS	5.83±1.03	5.42±1.51	**1.000** NS
Pre-CAL	6.83±0.94	5.75±1.06	4.168*	7.00±1.04	6.83±0.94	**0.518** NS
Post-CPL	5.83±1.40	6.75±1.23	1.89, NS	5.58±1.240	5.92±1.38	**1.000** NS
Post-CAL	7.29±1.17	6.25±0.97	5.000***	8.00±1.13	7.67±0.89	**0.715** NS
Precision	5.17±1.34	5.17±1.547	0.000NS	4.83±1.40	4.67±1.78	**0.364** NS
Performance	527.33±12.26	529.92±14.25	1.189 NS	526.58±13.173	526.67±12.64	**0.054** NS
SMR/ theta	0.3314±0.0895	0.3950±0.1015	4.980 NS	0.2962±0.1135	0.3001±0.0799	**0.238** NS
SMR epoch	7.1433±3.44	7.5358±2.93	0.870NS	8.6758 ± 4.19	8.2067± 3.51	**1.485**NS

Significant at 0.05 level two-tailed ** significant at 0.01 level two tailed. Pre- CPL: pre competition pleasure level Pre- CAL: pre competition arousal level, Post- CPL: post competition pleasure level, Post- CAL: post competition arousal level.

Statistical analyses were done using SPSS for Windows, version 16.0 (SPSS Inc., Chicago, IL). Paired 't' test and

Table 2. Independent 't' test results of post test measurements between Experimental and Control group archery players

Variables	Mean Difference	SE difference	't' value	'p' value
Heart Rate	3.750	3.362	1.115	0.277
Pre-CPL	1.417	0.512	2.768	0.011*
Pre-CAL	1.083	0.407	2.659	0.014*
Post-CPL	0.833	0.531	1.570	0.131
Post-CAL	1.417	0.379	3.742	0.001**
Precision	0.500	5.499	0.752	0.460
Performance	3.250	0.665	0.591	0.561
SMR/ theta ratio	0.094	0.037	2.544	0.018*
SMR epoch mean	0.670	1.319	0.508	0.616

**Significant at 0.05 level two-tailed ** significant at 0.01 level two tailed. Pre- CPL: pre competition pleasure level Pre- CAL: pre competition arousal level, Post- CPL: post competition pleasure level, Post- CAL: post competition arousal level*

Table 3. Pearson Correlation analysis- Baseline measurements of all variables of Experimental and Control group archery players.

Variables	Heart Rate	Pre- CPL	Pre- CAL	Post-CPL	Post-CAL	Perform	Precision	SMR/theta ratio	SMR epoch mean
Heart Rate	1								
Pre- CPL	-0.225	1							
Pre- CAL	-0.472 *	0.100	1						
Post- CPL	-0.194	0.293	0.186	1					
Post- CAL	-0.139	0.322	0.235	0.229	1				
Perform	0.121	-0.034 *	-0.104	-0.092	-0.143	1			
Precision	0.120	0.058	0.099	-0.099	-0.143	-0.116	1		
SMR/theta	-0.059	0.303	0.195	-0.447	-0.129	0.292	0.366	1	
SMR epoch mean	-0.102	0.169	-0.041*	-0.296	-0.205	0.028	0.346	0.611**	1

**Significant at 0.05 level two-tailed ** significant at 0.01 level two tailed. Pre- CPL: pre competition pleasure level Pre- CAL: pre competition arousal level, Post- CPL: post competition pleasure level, Post- CAL: post competition arousal level* independent 't' test were conducted to analyze the variables pre and post measurement of control and experimental subjects.

Results

The statistical analyses state the comparison of pre and post measurements of all variables in both groups, and also comparison of post measurements between the experimental and control groups (Tables 1 & 2).

The baseline measurements of both control and experimental group archers were analyzed with Pearson correlation test (see able-3). The analysis showed a statistically significant correlation between Heart Rate and Pre CAL (r=-0.472, p=0.05), Pre CPL and Performance (r=0-.034, p=0.05), Pre CAL and SMR epoch mean (r=-0.041, p=0.05) and SMR/theta ratio and SMR epoch mean (r=0.611, p=0.01).

All the control group variables were statistically non-significant when pre and post measurements were compared with paired 't' test. The experimental group showed statistically significant findings of pre-competition pleasure level (t= 2.768, p< 0.05), pre-competition arousal level (t= 2.659, p< 0.05), and post-competition arousal level (t= 3.742, p<0.001), but heart rate, post competition pleasure level, precision, performance and SMR epoch mean showed no statistically significant changes after neurofeedback training as compared with the control group. The present study results showed that when intra-group analysis was done, the experimental group had no changes in the precision level but the control group reduced the precision level after the duration of the study (Table.1). The mean value of pre and post measurements of the experimental group improved archery performance when compared with the control group (Table. 1). The inter-group analysis showed non-significant (t= 0.591, p= 0.561) changes between experimental and control groups for the same (Table. 2). The comparison of all the variables of the control group and experimental group archery players are shown in graphical presentation.

Discussion

Pleasure is an emotional factor of an athlete associated with their good performance, which may influence the next performance positively or negatively. The goal is for the optimal level of pleasure to be maintained by the athlete during the whole session of competition.

The closer the emotion scores were to poor performance scores in an elite archer was shown by case study (21). Arousal is another influencing factor of the performance which directly or indirectly affects the competitive state of the athlete. There appears to be a conflict of theories about the influence of arousal on performance. The optimal arousal level during competition enhances the optimal performance by regulation of psychological status of archery players. The results of the present study showed a significant regulation of the pre and post competition pleasure-arousal levels which helped archers to enhance their performance (Table- 1).

Heart rate showed no significant change when the experimental group was compared to the control group of archery players. However, after neurofeedback training, the experimental group of archers showed a significant (t= 2.310, p< 0.05) deceleration of heart rate. Deceleration in heart rate of experienced athletes in the few seconds prior to execution of a motor response has been reported in precision sports associated with good performance (7, 22). Dysfunctional conditions would be followed by poor shooting scores, incomplete shots, and possibly an increase in heart rate perceived by the athlete as detrimental arousal. Increased arousal associated with debilitating emotions could lead to lack of a heart rate deceleration pattern.

The increased cardiac cycle time (deceleration of heart rate) is related to the archery performance. The deceleration of heart rate is essential for the archer to maintain optimal performance. In the present study, inter-group analysis indicated a non-significant change in heart rate when the experimental group was compared with the control group. Baseline measurement of heart rate (physiological changes) during competition depended on the physical and psychological status of the athlete. Less change in HR during competition in the experimental group might have been due to the psychological factors such as pleasure-arousal levels or other unstudied factors.

Precision is the determining factor in precision sports, which requires optimum accuracy in scoring during competition. In archery, 'x' score is the high score when an archer shoots at the inner ring of the target board. This 'x' is the deciding factor if archers score equally during Olympics Rounds. Due to the SMR neurofeedback training, experimental archers were able to score more after completion and produced more 'x' scores in the post test evaluation. The present study result shows that when intra-group analysis was completed, the experimental group had no change in the precision level but the control group reduced its precision level after the duration of the study (see Table.1).

There are studies which reveal the effects of neurofeedback training on performance in various sports. One study was conducted to investigate the effect of SMR on enhancement of musical performance and concluded that slow wave neurofeedback training can benefit musical performance (3). In the present study, inter-group analysis showed no significant changes due to NFT in the experimental group. Comparatively, after completion of twelve sessions of NFT, the experimental group archers improved their performance over the control group archers.

An effective neurofeedback training tool consists of a compatible protocol which has to be chosen whether to inhibit or enhance the components of EEG frequency bands. Protocol-specific effects obtained in low beta/ SMR (12-15 Hz) training was associated with increased perceptual sensitivity and reduced omission errors and reaction time variability (13). Ten training sessions of both SMR and beta neurofeedback led to a significant reduction in the commission of errors compared with measures taken prior to training (14). The slow wave neurofeedback training beat1 (15-18 Hz), SMR (12-15 Hz) and alpha (8-12 Hz) /theta (4-7 Hz)) benefited musical performance under stressful conditions in healthy volunteers (15). The study has provided preliminary evidences of both alpha/ theta neurofeedback and HRV (Heart Rate Variability) biofeedback in improving dance performance. Additionally, the study authenticated validation of neurofeedback training for further research with sufficient evidence.

The study conducted on three groups of archery players found that the biofeedback group and control group archers showed poor performance due to the inappropriate EEG components induced during arrow shoot (7). But the result of the present study showed that the experimental group improved their archery performance when compared with the control group (Table. 1). The inter-group analysis showed non-significant changes between experimental and control groups for the same (Table. 2).

Finally, the study hypothesized that neurofeedback training regulates the psychological parameters to provide a composed mind-set for optimal performance. The occurrence of an optimal performance zone corresponding to the optimal arousal level, same as the present study, resulted with regulation of pleasure-arousal levels (23). The recent study of neurofeedback which stated that success of neurofeedback training in healthy individuals required time to focus on SMR frequency effectively, and concluded that we were unable to predict the learning of SMR neurofeedback in healthy individuals before eleventh session of training (5). The rewards received by subjects of the present study have shown that a successive increase in SMR frequency via NFT was consistent with the last session (12th session).

The application of neurofeedback training has been established in previous decades, however frequent usage of NFT must be practiced to achieve optimal levels of performance in different groups of athletes. The neurofeedback training has an essential role in the field of sports psychology. The evidence of research should support the effectiveness of NFT to promote its functional significance, such as use of functional neuro-imaging (FMRI) along with QEEG. Investigation of the functional neuro-imaging has illustrated the mechanism of the brain that stimulate regulation of autonomic arousal during behavioural changes which acts in response to internal feedback signals to manipulate the subjective feeling state (24).

Future studies should consider how regulation of EEG components with other psychological and physiological factors might promote the performance of athletes. Whereas, the study of neurofeedback on archers had found that this control group showed decreased precision and performance due to inappropriate EEG activity at the time of the arrow shot (7). The present study has limitations which include devoid of on field EEG measurement during archery performance sessions, and also comparison of NFT effect on left- and right- handed archers. The result of this study concluded that NFT enhanced regulation of psycho-physiological during the preparatory phase of competition, and also between subsequent arrow shots. It should be encouraged in all kind of sports to enhance the performance, especially in sports that require precision such as shooting or billiards.

In conclusion, the present study hypothesized that neurofeedback regulates the psycho-physiological measures to provide a composed effect for optimal performance through attaining deceleration of the heart rate during archery performance, regulation of pre and post competition pleasure-arousal level during competition, and enhancement of EEG components. The practical implications of the study include 1) neurofeedback training regulates the mental status of the athletes, 2) regulation of mental status help an athlete's ability to decelerate the heart rate to improve accuracy in archery and 3) that enhancement/ inhibition of particular brain wave frequency could be attained by this training.

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References

1. Gould D, Krane V. The arousal-athletic performance relationship: Current status and future directions. Advances in Sports Psychology (2nd ed.) 1992, Champaign, IL: Human Kinetics.
2. Vernon DJ. Can neurofeedback training enhance performance? An evaluation of the evidence with implication for future research. Appl Psychophysiol Biofeedback 2005;30:347-64.
3. Sterman MB, Wyrwicka W and Roth SR. Electrophysiological correlates and neural substrates of alimentary behavior in the cat. Ann N Y Acad Sci 1969;157:723–39.
4. Egner T and Gruzelier JH. Ecological validity of neurofeedback: modulation of slow wave EEG enhances musical performance. NeuroReport 2003;14:1221-4.
5. Vernon DJ, Egner T, Cooper N, Compton T, Neilands C, Sheri A and Gruzelier J. The effect of training distinct neurofeedback protocols on aspects of cognitive performance. Int J Psychophysiol 2003;47:75-85.
6. Weber E, Koberl A and Doppelmeyr M. Predict successful learning of SMR neurofeedback in healthy participants: methodology consideration. Appl Psychophysiol Biofeedback 2010. DOI: 10.1007/s10484-010-9142-x.
7. Landers DM, Petruzzello SJ, Salazar W, Crews DJ, Kubitz KA, Gannon TL and Han M. The influence of electrocortical biofeedback on performance in pre-elite archers. Med Sci Sports Exerc 1991;23:123-29.
8. Collura TF. Application of repetitive visual stimulation to EEG Neurofeedback protocol. J Neurother 2002; 6:47-70.
9. Collura TF. A neurofeedback to approach improving at golf and other sports. Golf Neurofeedback 2003;1-7.
10. Landers DM. Psycho-physiological assessment and biofeedback: Application for athletes in closed skills sports. Biofeedback and Sports Sciences (J.H. Sandweiss & S.L. Wolf ed.). 1985; New York: Plenum Press.
11. Norris SL , Currieri M. Performance enhancement training through neurofeedback. Introduction to quantitative EEG and neurofeedback 1999 (J.R. Evans & A. Abarbaanel ed). San Diego: Academic Press.
12. Wilson VE, Gunkelman J. Neurofeedback in sports. Biofeedback 2001;29:16-8.
13. Egner T, Gruzelier JH. EEG Biofeedback of low beta band components: Frequency specific effects on variables of attention and event-related brain potentials. Clin Neurophysiol 2004;115:131-9.
14. Gruzelier J, Egner T, and Vernon DJ. Validating the efficacy of neurofeedback for optimizing performance. Prog Brain Res 2006;159:421-31.
15. Raymond J, Sajid I, Parkinson LA and Gruzelier JH. Biofeedback and dance performance: A preliminary investigation. Appl Psychophysiol Biofeedback 2005;30:65-73.
16. Egner T and Gruzelier JH. Learned self-regulation of EEG frequency components affects attention and event-related brain potentials in humans. Neuro Report 2001;12:4155-9.
17. Vernon DJ, Frick A, and Gruzelier J. Neurofeedback as treatment for ADHD: A methodological review for further research. J Neurother 2004;8:53-82.
18. Fedotchev AI. Efficacy of EEG biofeedback procedures in correcting stress-related functional disorders. Hum Physiol 2010;36:86–90.
19. Ertan H, Soylu AR and Korkusuz F. Quantification the relationship between FITA scores and EMG skill indexes in archery. J Electromyogr Kinesiol 2005;15:222-7.
20. Russell JA, Weiss A and Mendelsohn GA. Affect grid: A single-item scale of pleasure and arousal. J Pers Soc Psychol 1989;57:493-502.
21. Robazza C and Bortoli C. Performance emotions in an elite archer- A case study. J Sport Behav 2000;23:144-63.
22. Boutcher SH and Zinsser NW. Cardiac deceleration of elite and beginning golfers during putting. J Sports Exerc Psychol 1990;12:37-47.
23. Filho ESM and Moraes LC. Affective and physiological states during archery competitions: adopting and enhancing the probabilistic methodology of individual affect-related performance zones

(IAPZs). J Appl Sports Psychol 2008;20:441-56.
24. Critchley HD. Neural mechanisms of autonomic, affective and cognitive integration. J Comp Neurol 2005;493:154–66.