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Developing a Performance Brain Training™ Approach for Baseball: A Process Analysis with Descriptive Data

Leslie H. Sherlin · Noel C. Larson · Rebecca M. Sherlin

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Abstract Neurofeedback may be useful for improving sports performance but few studies have examined this potential. Here we present data of five development players from a major league baseball team. The aims were to evaluate the feasibility of conducting sessions within a professional organization, assess changes in quantitative electroencephalograph (QEEG), NeuroPerformance Profile™, and report qualitative self-report data before and after brain training. The EEG was recorded with 19 electrodes for 20 min of baseline conditions and approximately 21 min of a continuous performance test. The fast Fourier transform analysis provided average cross-spectral matrices for bands delta (1–3.5 Hz), theta (4–7.5 Hz), alpha (8–12 Hz), low beta (13–16 Hz), beta 1 (13–21 Hz), beta 2 (22–32 Hz), and gamma (32–45 Hz) from the pre and post intervention evaluations in the baseline condition of eyes open. The continuous performance test metrics included the errors of omission, errors of commission, response time and response time variability. The 9 scales of the NeuroPerformance Profile™ were examined. The QEEG data, CPT data and NeuroPerformance Profile™ data were all compared between the pre and post 15 sessions of brain training using a within subject paired *t* test design corrected for multiple comparisons using false discovery rate method. Following brain training, comparative QEEG, CPT and NeuroPerformance Profile™ analyses illustrated significant differences. The QEEG findings of all participants illustrated significant changes within the training parameters but also across other frequency bands and electrode sites. Overall, the positive findings in both objective and subjective measures suggest further inquiry into the utility of brain training for performance enhancement with the specific application of sport is warranted. Particularly QEEG and CPT gains were noted in the areas that correspond to client self-report data demonstrating improvement in attention, decreased intrusive thought patterns and improvements in sleep patterns.

Keywords Neurofeedback · Sport · Baseball · QEEG · Brain Training · NeuroPerformance Profile™

L. H. Sherlin (✉) · N. C. Larson
Neurotopia, Inc., 2801 Townsgate Rd #214, Westlake Village, CA 91361, USA
e-mail: LeslieSherlin@mac.com; lsherlinphd@neurotopia.com

R. M. Sherlin
Nova Tech EEG, Inc., Mesa, AZ, USA

Introduction

Many would agree that understanding the neurophysiological mechanisms underlying performance differences between experts and amateurs is the next frontier of peak performance training (Harung et al. 2011; Thompson et al. 2008). Cortical activity of competitors has been studied extensively across numerous disciplines to understand that which separates excellent from poor performers. Research measuring this activity with electroencephalography (EEG) of athletes during pre-task periods, imagined tasks, and performance of tasks has identified patterns of brain activity that differentiate elite from novice athletes. Experts in diverse fields [e.g., golfers (Baumeister et al. 2008), archers (Kim et al. 2008), and marksmen (Hillman et al. 2000)] demonstrate consistencies in EEG findings. Broadly, compared to amateurs in the respective field, experts utilize *only* necessary neural connections while simultaneously inhibiting activation in unrelated cortical areas (Deeny et al. 2009).

Understanding how elite performers operate from a cortical perspective allows for the development of customizable training programs that go beyond traditional skill rehearsal and physical strengthening paradigms by directly enhancing mental functioning with neurofeedback training (also called EEG training). Neurofeedback is a process that involves assessing cortical activity via an EEG and subsequently reflecting it back in real time. This creates a continuous feedback loop allowing purposeful learning through classical and operant conditioning of the changes in cortical activity; specifically a reward is earned when the EEG activity is at the desired levels (Lofthouse et al. 2011; Sherlin et al. 2011).

Already neurofeedback training has been employed for athletic performance improvements in golfers (Arns et al. 2007) and archers (Landers et al. 1991). In both studies participants improved on performance measures after neurofeedback training, but this field of research is limited. Currently, no standardized practices exist for training athletes with neurofeedback to improve performance. It is unclear if there are particular athletes that respond better to this type of training, or if there are specific training protocols that work best, or if there is a necessary minimum number of training sessions for improvements to occur.

Without uniform training paradigms, neurofeedback will continuously be held back by methodological limitations. One such solution to this problem may be training based from the NeuroPerformance Profile™ (Sherlin and Hixson 2011), which is a report generated from quantitative electroencephalography (QEEG) analysis (Pascual-Marqui et al. 1994) derived from numerous scalp electrodes allowing the localization of electrical activity. Employing a QEEG analysis offers a complete picture and valid measure of cortical activity. The outcomes of the NeuroPerformance Profile™ are based on EEG activity during baseline and a continuous performance test (CPT), along with the behavioral outcomes on the CPT (errors, response time, and response time variability) and changes in EEG between the differing conditions. The NeuroPerformance Profile™ is an attempt at combing behavioral performance with relevant neurophysiological functioning to produce output data that is both meaningful and comprehensible to an athlete population that does not have specific knowledge of EEG or psychometric testing. Translating the results into the NeuroPerformance Profile™ we believe may allow for better comprehension by the athletes, coaching staff, and trainers as to which cognitive skills are strengths and which are weaknesses. Thus, the NeuroPerformance Profile™ may provide a better guide to selecting training protocols.

The current feasibility and outcome study is a multiple-case design that offers a first attempt to measure demonstrable physiological and performance changes on a CPT in baseball players following the implementation of a specific neurofeedback paradigm (Performance Brain Training™). Our interest is to determine outcomes of change in standard and basic QEEG metrics (e.g., power and percent power at the scalp level), improvements in the NeuroPerformance Profile™ and qualitative (subjective interview) reports of change from the participants. If positive outcomes are obtained the applicability of Performance Brain Training™ training programs specifically can be evaluated for feasibility and efficacy in future investigations.

Methods

Participants

Participants were six male professionals currently on the development team roster for a Major League Baseball organization in the American League West Conference. The team training staff chose the athletes to participate based on individual ability, willingness and commitment to follow through the entire training regimen. The participants were additionally identified as players who were on the cusp of being brought up to the next level team, in this case AAA, and were believed to be key players and likely to be serious prospects for the Major League team. Following the player selection, evaluations were performed to determine appropriate training protocols based on individual strengths and weaknesses and desired areas for performance improvement.

This incidental sample of baseball professionals was chosen for the current study because of an existing relationship with the team and an interest for evaluating the potential benefits and practicality of implementation on a large scale with the team. To our knowledge, neurofeedback has not been studied in baseball players. Our sample of convenience dictated the position of the players that participated in the training, although there is no theoretical reason or previous finding rationalizing that any specific position would respond better or worse than another.

EEG Data Collection

For each subject EEG data was collected continuously in a dimly illuminated and sound attenuated room. The EEG was sampled with 19 electrodes in the standard 10–20 International placements referenced to linked ears. Impedances were all below 5 kOhms and within 1.5 kOhm difference between sites. Data was collected using the Mitsar 201 M amplifier, WinEEG software (Mitsar Ltd, St. Petersburg, Russia) and electrode caps (Electro-Cap Intl. Inc., Eaton, OH) for 10 min of eyes closed baseline, 10 min of eyes open baseline, and approximately 21 min of the QIKtest continuous performance test (BEE Medic

GmbH, Kirchberg, Switzerland) sampled and stored at 250 samples per second.

Measures

Quantitative Electroencephalography

Data was plotted and carefully inspected using manual artifact-rejection for all tasks. All episodic artifacts including eye blinks, eye movements, teeth clenching, body movements, or EKG artifact was removed from the stream of EEG. All recorded participants had acceptable quality data after performing the artifacting procedure. For the QEEG, only data during baseline and post intervention baseline of the eyes open condition is analyzed in the current study. The fast Fourier transform (FFT) analysis provided average cross-spectral matrices for bands delta (1–3.5 Hz), theta (4–7.5 Hz), alpha (8–12 Hz), low beta (13–16 Hz), beta 1 (13–21 Hz), beta 2 (22–32 Hz), and gamma (32–45 Hz). The spectral analyses of the pre-post comparison calculations were completed using the WinEEG software (Mitsar, Ltd, St. Petersburg, Russia).

Continuous Performance Test

The QIKtest continuous performance test (BEE Medic GmbH, Kirchberg, Switzerland) was used to provide two stimuli (target and non-target) to record participant response time, response time variability, errors of omission and errors of commission. The QIKtest CPT is a battery powered stand alone device that presents visual stimulus in an LED array and auditory stimulus. This study utilized only the visual stimuli to track measures with a time measurement resolution of 0.1 ms. The test challenges the participant under both high-demand and low-demand conditions in five segments (low, low, high, high and low demand) (Othmer 2008).

NeuroPerformance Profile™

The NeuroPerformance Profile™ is designed to measure key elements that contribute to the mental/cognitive aspects of performance, particularly in athletes. The indices and scales provide a summary to quantitative values otherwise complicated by jargon and concepts that are difficult for the client to integrate. The evaluation is based on a combination of both behavioral and physiological data. The NeuroPerformance Profile™ includes QEEG spectral information from the eyes closed, eyes open and the varying time periods of the CPT as well as the resultant behavioral analysis of the CPT performance. The NeuroPerformance Profile™ is an analysis that computes neurocognitive domains or constructs applicable to performance utilizing QEEG spectral output in combination with behavioral performance on a continuous performance task (Sherlin and Hixson 2011). A brief and general description of each construct is included to further understand the parameters as they relate to this study.

The NeuroPerformance Profile™ contains three indices. These are the *Focus Index*, the *Stress Index*, and the *Speed Index*. The Focus Index is composed of cortical and behavioral variables of attention and concentration. This index is constructed to provide information about the individual's baseline attention ability as well as the ability to pay attention and to do so over a lengthy period of time. The Stress Index is composed of variables of activation of the cortex during varying degrees of engagement. This index is constructed to provide insight into the individual's arousal level and how well the individual is able to deal with stress under low demand, high demand and return to low demand tasks. Finally the Speed Index is composed of variables of response to stimuli, consistency of response and physiological measurements indicating cognitive processing speed. This index is constructed to provide insight into the cognitive processing ability of the individual at the baseline state and to evaluate at what degrees can the individual process information and make a correct response.

Each Index is further broken down into 3 scales to provide more specific and detailed information about the abilities of the individual.

Focus Index

1. *NeuroStrength Scale* reflects the degree at which the individual is able to focus on a moderate to low stimulating task.
2. *Impulse Control Scale* is easily understood as the individual's ability to activate the cortical regions associated with impulse control and the accuracy of not committing errors of commission.
3. *Focus Endurance Scale* indicates the ability of the individual to maintain cortical activation associated with focus and attention across a long period of time both in baseline and activation tasks.

Stress Index

4. *NeuroAgility Scale* reflects and individual's ability to adapt to increasing the complexity of demands. The scale is composed of cortical arousal levels as the demand changes (baseline, low demand and high demand tasks) as well as behavioral response time to stimuli.
5. *Stress Optimization Scale* recognizes the ability of the individual to increase arousal under high demand

challenge task and decrease arousal when the task demand is lower or during the baseline condition. The scale is most interested in the variability between these time periods and not the actual values.

6. *Stress Recovery Scale* is correlative to the individual's ability to "reset" or dismiss errant behavior. The algorithm strongly considers the Stress Threshold metric and the cortical implications associated with dissipation (opposite of rumination).

Speed Index

7. *NeuroSpeed Scale* reflects the individual's cortical processing speed. The scale is a calculation derived from the posterior dominant rhythm (peak alpha frequency) and the maximum reaction speed of the cortex to a given stimuli.
8. *Reaction Speed Scale* indicates the speed at which an individual responds to stimuli both cortically and behaviorally. Reaction speed is calculated by processing the time lapse between cortical response and behavioral reaction to presenting target or non-target stimuli.
9. *Accuracy/Timing Scale* represents the variability of speed at which an individual responds to stimuli. The scale identifies the consistency of responses and reaction speeds under low and high demand challenges and across a long period of time.

The Profile Indexes are displayed in the NeuroPerformance Profile™ to the client as a spider graph with a percentage value (Fig. 1). The percentage value is based on a total possible of 100 and the lowest a 0.

Neurofeedback Training

Given the connection between standard neurofeedback protocols, positive outcomes, and QEEG changes among clinical populations, the current study utilized neurofeedback protocols based on the NeuroPerformance Profile™ (Sherlin and Hixson 2011) previously described. Each scale has an associated protocol that addresses the EEG components that are used in the algorithm for calculating the scale. As an example, the Impulse Control scale has behavioral contribution from the CPT test errors of commission, but it additionally considers the electrical activity in combination of slow wave and fast wave contribution to the total across a combination of frontal lobe electrode sites in the eyes closed, eyes open and CPT task. Information has been provided below with regard to the general inhibit and reward characteristics and electrode placements for the neurofeedback training parameters. Each of the athletes in this study followed a training protocol that was consistent with their weakest scores matched with personal training goals for improvement. A table of client training protocols is provided to summarize the differences in the parameters of training (Table 1).

The training sessions were conducted at various times of the day across a 30-day period. The goal was to achieve a consistent training routine with a minimum of 2–3 sessions per week, once per day. Due to training, practice and game schedules the neurofeedback sessions averaged 3 sessions

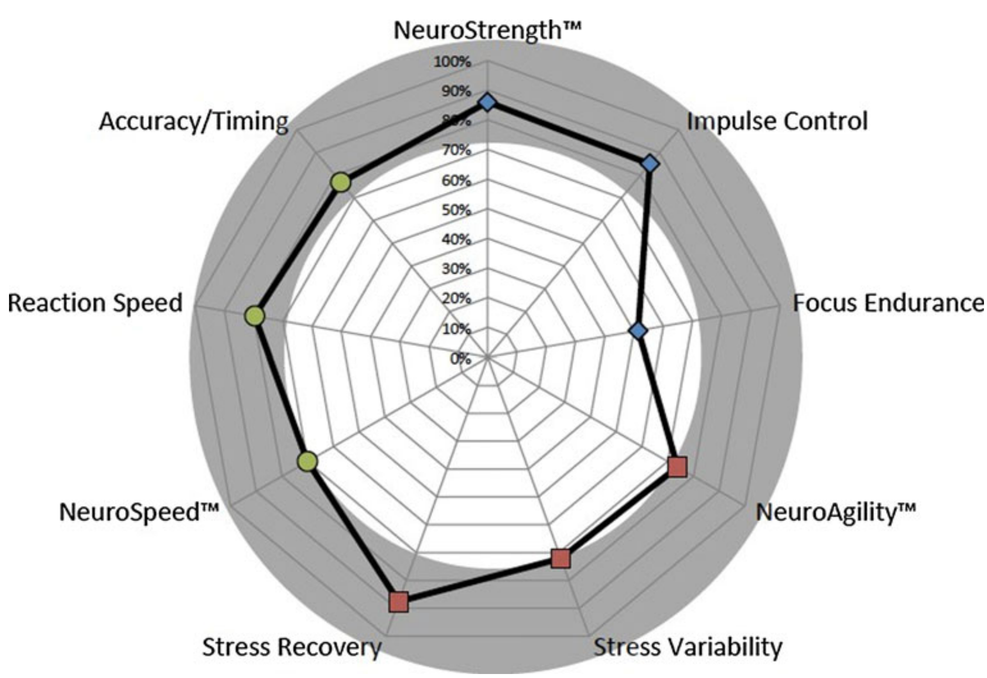

Fig. 1 The NeuroPerformance Profile™ spider graph used to display the 9 scales

Table 1 Performance brain training parameters

Subject	Cortical areas	Training parameters
SS1	Bilateral parietal	NeuroAgility: mixed training to sometimes inhibit slow-mid spectral range and augment fast and other sessions augment mid range and inhibit fast frequencies
SS2	Right frontal Right central	NeuroAgility: mixed training to sometimes inhibit slow-mid spectral range and augment fast and other sessions augment mid range and inhibit fast frequencies
SS3	Central bilateral Frontal bilateral	Focus endurance: inhibit slow spectrum and augment selected ranges of fast frequencies
SS4	Right Frontal Right central	NeuroAgility: mixed training to sometimes inhibit slow-mid spectral range and augment fast and other sessions augment mid range and inhibit fast frequencies
SS5	Right frontal	Impulse Control Scale: Inhibit slow spectrum and augment selected ranges of fast frequencies

per week but were not always evenly spaced with some sessions being on consecutive days followed by as much as a 3 day break. All sessions were conducted using a standard computer with dual monitors using BioExplorer software (CyberEvolution, Inc., www.cyberevolution.com) and visual and auditory feedback was provided to the client using either Dual Drive Xtreme or Particle Editor software (Somatic Vision, Inc., www.SomaticVision.com). The Dual Drive Xtreme feedback screen is one where a type of automotive vehicle is presented in a race format. As the client succeeds at the predefined protocol parameters the automobile will move forward at a speed that corresponds to their success (e.g. slow if minimally making thresholds or faster if activity is well above/below thresholds). When any threshold is not exceeded all feedback is stopped. Music is also presented when feedback is being given and stops when any threshold is not met. The Particle Editor software provides a variety of shapes or lines that are in movement along with music when the session protocol parameters are met. When any threshold is not met the feedback, both visual and auditory, are stopped. Sessions were a minimum of 20 min and a maximum of 35 min in duration with variation occurring due to late arrivals or necessary early departures from the session due to the other team demands. The total number of sessions was 15 for each participant. Each participant trained the same protocol for all 15 sessions. Based on previously described learning theory for implementation of neurofeedback (Sherlin et al. 2011), each session had a threshold derived from a 2 min baseline recording to give the participant a 75 % reward rate. The reward rate percentage was monitored and when the participant was receiving feedback at a rate higher than 80 % the threshold was adjusted based on the previous 2 min to a new threshold that would be at a 75 % reward rate. If the reward rate fell below 70 % the session was paused so the client could rest for 30–60 s and the session was restarted. If this occurred more than twice a new threshold was set in the same fashion as when they had began the session. These sessions were part of the spring training program and took place at the professional baseball club's spring training facility in Peoria, AZ. Sessions were conducted by a certified and extensively trained technician. The technician did not provide sport specific feedback but only concepts that were related to succeeding during the training session. The sport psychology consultant for the team and trainers discussed with the participants what they were learning during the neurofeedback sessions and related these concepts to their play in sport.

Data Analysis

Because the training paradigm was individualized to each participant, and because of the small sample size and exploratory nature of the study, the QEEG analyses have been treated as a multiple cases study design. The CPT and the NeuroPerformance Profile™ results are tabulated on a pre-post change of the group. For the QEEG metrics each participant's baseline evaluation in the eyes open condition was compared to the post-intervention evaluation. The eyes open condition baseline was chosen for comparison because the training had taken place with visual feedback (eyes open condition) and therefore we expected any changes to be most prominent in this condition. For each subject, relative power means within the frequency bands were computed at each electrode site for the pre and post training evaluations. Relative power is the normalized or percent power (microvolts squared of frequency band/microvolts squared of the total frequency bands) for each frequency band. As previously mentioned, it should be recognized that for the QEEG analysis that there were too few participants to have meaningful group data and as such a pre-post comparison *t* test for each individual was made with the null hypothesis that there was no change in QEEG findings of the 7 frequency bands at each of the 19 sites for each subject. To control for the multiple comparisons the well-known false discovery rate (FDR) multiple testing procedures of Benjamini and Hochberg (1995) was implemented considering the *p* values of all subjects (5) across all frequency bands (7) and all electrode sites (19). The FDR procedure was utilized because the Bonferroni's approach ignores that *p* values are not equally distributed. The FDR on the other hand has a higher *t* statistic than those with the nominal alpha-p level where rejecting H0 is the better choice. In the FDR method the most significant value is being corrected at Bonferroni level and next most significant value is corrected at twice this rate and so forth until one value (in this ascending list of *p* value sorted voxels) is found that does not meet with the correction criterion ($p(V) > (i/N) \times q$). At this point then all subsequent values are assumed to belong to the falsely claimed active values (Yekutieli and Benjamini 1999). The FDR has been proposed and utilized in other brain imaging techniques where many comparisons are made in order to control the family-wise error rate (Genovese et al. 2002).

Just as the *p* value provides a measure of significance for a data set the q value accomplishes this same goal with regard to the FDR. The smaller the q value the more significant the differential expression. As of now there are no conventional methods for establishing the q value for FDR. An FDR of 20 % would keep within the practice of accepting 5–10 % false positive single results (Storey 2002; Storey and Tibshirani 2003; Storey et al. 2004). Additionally some report that the q value should be set at where the histogram of the *p* values flattens. This can be seen to occur at 0.10 in this data set in Fig. 2. The q value was therefore set at 0.1. CPT measures of errors of omission, errors of commission, response time, and response time variability were calculated. No comparison to normative or other population was made. This CPT test is utilized to simply record the metrics for a paired pre-post comparison rather than evaluating values compared to an expected normal population. Statistical comparisons between pre and post measures were made using a paired sample *t* test in the aforementioned measures.

NeuroPerformance Profile™ scales are each based on a percentage value. The percentage values were summed and differences between the pre and post scales are reported at the group level. By summing the scales percentage points an overall and comprehensive change can be evaluated. This is an important procedure because many of the individual scales increased or decreased despite not being part of the targeted training protocols. Because of the pilot nature of this initial evaluation and the first use of this test with actual participant data following intervention, it was decided a priori that it would be examined from a summative perspective. Again, statistical comparisons of the group was calculated using a within subject paired sample *t* test to evaluate change. Results reported on the group level reflect changes in the total of all scales and reflect comprehensive change in all scales. Analyses were conducted using StatPlus:Mac2009 (AnalystSoft, Inc., Vancouver, BC) and were evaluated for statistical significance using an alpha level of 0.05.

Results

There were five participants completing a full 15 sessions of the neurofeedback training and a repeat evaluation. All participants were male and the mean age was 19.20 ($SD = 0.45$, $SEM = 0.20$, $N = 5$). The sample consisted of one Native Hawaiian and four Caucasian players with mixed baseball positions on the field (3 pitchers, 1 catcher, and 1 short stop). These differences are not believed to have an impact on changes reported in QEEG, CPT or NeuroPerformance Profile™ measures or to be a factor in subjective reports. However, it is acknowledged that the sample is so small that this study cannot rule out that characteristics of one position may be more suitable for demonstrating change. All subjects had suitable and interpretable pre and post intervention evaluations of QEEG and CPT testing.

Individual Enhancement in QEEG Measures and Subjective Participant Feedback

Participant 1 (Catcher)

The post QEEG changes corrected for multiple comparisons included trending decreases of parietal theta along

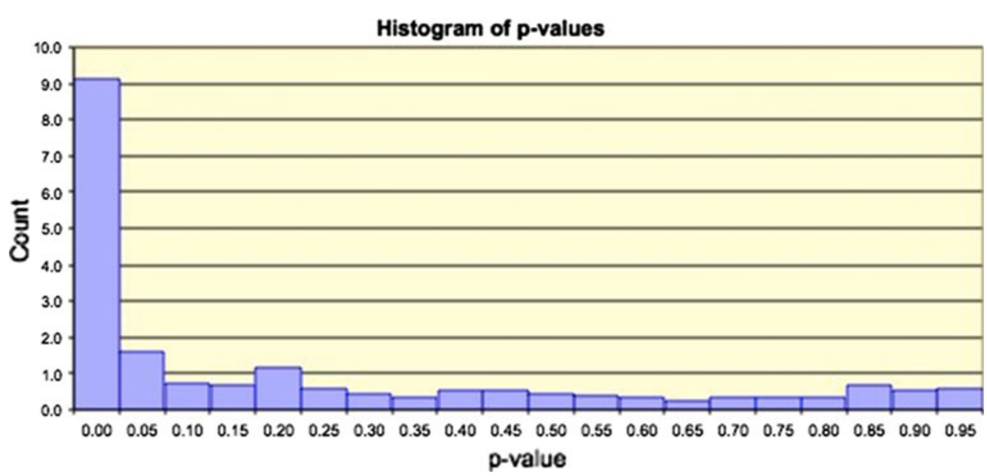

Fig. 2 Density histogram of the observed 665 p-values indicating that values beyond 0.1 are null in this region

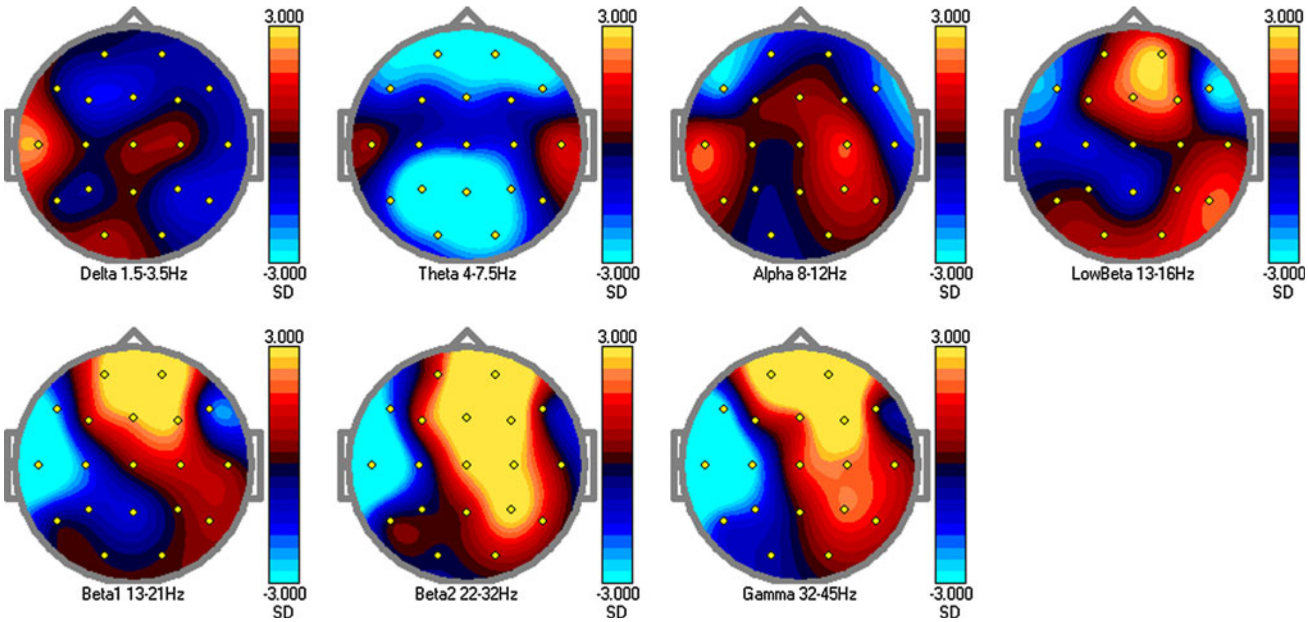

Fig. 3 QEEG topographies of Z-Score differences between pre and post evaluation of Participant 1. *Positive values* indicate increases and *negative values* indicate decreases in post evaluation percent power

Table 2 Comparison of normalized power spectra (%), normalization frequency band 0.0–64.0 Hz

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	$-1.04\ p < 0.690$	$-5.99\ p < 0.012$	$-3.43\ p < 0.201$	$-0.01\ p < 0.733$	$2.85\ p < 0.017$	$0.86\ p < 0.186$	$1.47\ p < 0.002$
Fp2-Ref	$-2.05\ p < 0.494$	$-6.34\ p < 0.002$	$-0.80\ p < 0.733$	$1.03\ p < 0.023$	$3.72\ p < 0.002$	$3.34\ p < 0.001$	$1.52\ p < 0.001$
F7-Ref	$-0.71\ p < 0.751$	$-4.05\ p < 0.067$	$-4.89\ p < 0.040$	$-1.03\ p < 0.073$	$-3.44\ p < 0.044$	$-4.29\ p < 0.053$	$-2.26\ p < 0.010$
F3-Ref	$-4.62\ p < 0.165$	$-2.14\ p < 0.331$	$0.83\ p < 0.990$	$0.05\ p < 0.521$	$0.56\ p < 0.396$	$0.56\ p < 0.186$	$0.11\ p < 0.872$
Fz-Ref	$-3.93\ p < 0.224$	$-4.37\ p < 0.069$	$2.83\ p < 0.572$	$0.53\ p < 0.052$	$1.30\ p < 0.025$	$1.18\ p < 0.003$	$0.26\ p < 0.085$
F4-Ref	$-1.04\ p < 0.772$	$-2.90\ p < 0.228$	$1.37\ p < 0.908$	$0.73\ \mathrm{p} < 0.113$	$1.80\ p < 0.029$	$2.35\ \mathrm{p} < 0.001$	$1.05\ p < 0.001$
F8-Ref	$-2.10\ p < 0.434$	$-4.85\ p < 0.034$	$-4.25\ p < 0.098$	$-0.95\ p < 0.023$	$-1.47\ p < 0.112$	$0.67\ p < 0.992$	$0.11\ p < 0.889$
T3-Ref	$2.87\ p < 0.035$	$0.51\ p < 0.565$	$5.11\ p < 0.089$	$-0.98\ p < 0.246$	$-6.20\ p < 0.002$	$-8.76\ p < 0.001$	$-4.69\ p < 0.002$
C3-Ref	$-0.18\ p < 0.971$	$-1.81\ p < 0.281$	$1.67\ p < 0.909$	$-0.61\ p < 0.192$	$-1.29\ p < 0.075$	$-1.06\ p < 0.167$	$-0.76\ p < 0.017$
Cz-Ref	$0.13\ p < 0.638$	$-3.39\ p < 0.171$	$1.86\ p < 0.858$	$0.10\ p < 0.909$	$0.50\ p < 0.593$	$0.84\ p < 0.016$	$0.22\ p < 0.153$
C4-Ref	$0.57\ p < 0.609$	$-2.44\ p < 0.289$	$4.35\ p < 0.097$	$-0.01\ p < 0.866$	$0.93\ p < 0.228$	$1.30\ p < 0.011$	$0.60\ p < 0.064$
T4-Ref	$-2.55\ p < 0.398$	$2.33\mathrm{p} < 0.211$	$-3.07\ p < 0.232$	$0.36\ p < 0.609$	$0.34\ p < 0.665$	$-0.00\ p < 0.859$	$0.12\ p < 0.316$
T5-Ref	$-0.66\ p < 0.780$	$-3.83\ p < 0.062$	$3.27\ p < 0.530$	$-0.14\ p < 0.842$	$-0.65\ p < 0.726$	$0.14\ p < 0.964$	$-0.29\ p < 0.124$
P3-Ref	$-1.92\ p < 0.559$	$-6.58\ p < 0.001$	$1.26\ p < 0.861$	$-0.31\ p < 0.965$	$-1.01\ p < 0.394$	$0.11\ p < 0.865$	$-0.19\ p < 0.115$
Pz-Ref	$0.27\ p < 0.911$	$-7.79\ p < 0.001$	$2.13\ p < 0.895$	$-0.87\ p < 0.232$	$-1.25\ p < 0.226$	$0.55\ p < 0.536$	$0.01\ p < 0.830$
P4-Ref	$-3.43\ p < 0.239$	$-3.96\ p < 0.031$	$4.77\ p < 0.232$	$0.01\ p < 0.506$	$-0.12\ p < 0.842$	$1.08\ p < 0.006$	$0.15\ p < 0.060$
T6-Ref	$-3.81\ p < 0.172$	$-1.04\ p < 0.597$	$1.91\ p < 0.488$	$1.45\ p < 0.085$	$0.52\ p < 0.459$	$0.57\ p < 0.209$	$0.10\ p < 0.201$
O1-Ref	$0.88\ p < 0.480$	$-3.77\ p < 0.019$	$-2.14\ p < 0.620$	$0.19\ p < 0.489$	$-0.39\ p < 0.943$	$0.09\ p < 0.874$	$-0.16\ p < 0.440$
O2-Ref	$-1.07\ p < 0.749$	$-4.52\ p < 0.009$	$0.64\ p < 0.798$	$0.07\ p < 0.320$	$-0.37\ p < 0.992$	$0.27\ p < 0.410$	$-0.00\ p < 0.543$

Electrode site and frequency band *p* values of differences in Participant 1. Positive values indicate increases and negative values indicate decreases in post evaluation percent power

with significant elevations of frontal and central beta. There were significant increases of alpha band in the parietal and left temporal sites as well (Fig. 3; Tables 2, 3).

Participant reported that "he goes straight to sleep and he has been able to shut his mind off" at session 6. He reported that "he is more focused when people are talking to him" at session 9.

Table 3 Corrected *p* values with the false discovery rate method for participant 1

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	0.341968366	0.341968366	0.171436123	0.392718121	0.01337069	0.0144	0.0144
Fp2-Ref	0.267385797	0.267385797	0.150837209	0.032228571	0.029573034	0.003241379	0.003241379
F7-Ref	0.363262436	0.363262436	0.282	0.122295918	0.275578748	0.058495356	0.058495356
F3-Ref	0.120232558	0.120232558	0.012533333	0.232032587	0.020304	0.196924051	0.196924051
Fz-Ref	0.1504	0.1504	0.421710366	0.156878378	0.282	0.059687117	0.059687117
F4-Ref	0.370875639	0.370875639	0.018721992	0.122794937	0.282	0.151284706	0.151284706
F8-Ref	0.244776	0.244776	0.282	0.120232558	0.196147992	0.033760563	0.033760563
T3-Ref	0.034270833	0.034270833	0.282	0.282	0.282	0.294510166	0.294510166
C3-Ref	0.418688073	0.418688073	0.060672727	0.254352941	0.282	0.173776316	0.173776316
Cz-Ref	0.320705882	0.320705882	0.044673267	0.412221529	0.003241379	0.12270229	0.12270229
C4-Ref	0.311119565	0.311119565	0.401884058	0.264340509	0.282	0.176785249	0.176785249
T4-Ref	0.229991803	0.229991803	0.018721992	0.42321203	0.357923077	0.143033654	0.143033654
T5-Ref	0.372813559	0.372813559	0.003241379	0.065911243	0.282	0.055154574	0.055154574
P3-Ref	0.292463822	0.292463822	0.028732075	0.413775701	0.282	0.282	0.282
Pz-Ref	0.404570079	0.404570079	0.099	0.035006897	0.282	0.282	0.282
P4-Ref	0.153177273	0.153177273	0.019567347	0.218228216	0.282	0.031789091	0.031789091
T6-Ref	0.122794937	0.122794937	0.092722826	0.39592053	0.175330435	0.306098182	0.306098182
O1-Ref	0.263859649	0.263859649	0.411746479	0.24849505	0.282	0.021261905	0.021261905
O2-Ref	0.364168966	0.364168966	0.418465544	0.031789091	0.282	0.011642202	0.011642202

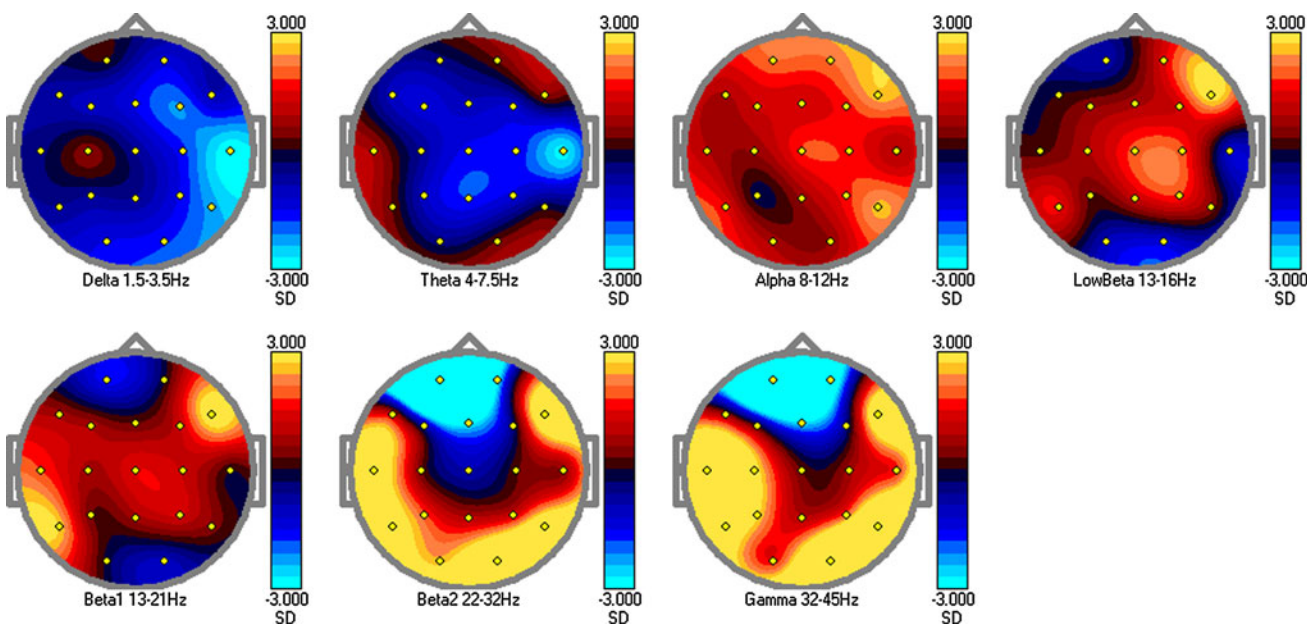

Fig. 4 QEEG topographies of Z-Score differences between pre and post evaluation of Participant 2. *Positive values* indicate increases and *negative values* indicate decreases in post evaluation percent power

Participant 2 (Pitcher)

The post QEEG changes corrected for multiple comparisons included significant increases of alpha and beta with maximal increases across the parietal cortex. There were significant reductions in the theta and delta bands frontally (Fig. 4; Tables 4, 5).

Participant reported "reports he goes to sleep much better and stays asleep" at session 4. At session 5 he stated that he "is a lot more focused on the mound and stayed focused for

Table 4 Comparison of normalized power spectra (%), normalization frequency band 0.0–64.0 Hz

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	−0.04 $p < 0.996$	0.65 $p < 0.659$	8.65 $p < 0.046$	−0.14 $p < 0.417$	−0.66 $p < 0.112$	−4.78 $p < 0.001$	−1.19 $p < 0.001$
Fp2-Ref	−3.26 $p < 0.183$	1.82 $p < 0.747$	7.82 $p < 0.044$	0.90 $p < 0.162$	0.62 $p < 0.988$	−0.84 $p < 0.009$	−0.52 $p < 0.002$
F7-Ref	−2.08 $p < 0.423$	−1.38 $p < 0.302$	3.89 $p < 0.395$	0.01 $p < 0.999$	0.23 $p < 0.447$	0.44 $p < 0.271$	0.05 $p < 0.488$
F3-Ref	−2.37 $p < 0.279$	−1.11 $p < 0.181$	6.25 $p < 0.237$	0.24 $p < 0.603$	0.64 $p < 0.429$	−0.08 $p < 0.479$	0.03 $p < 0.973$
Fz-Ref	−3.59 $p < 0.134$	−0.63 $p < 0.329$	5.47 $p < 0.228$	0.34 $p < 0.441$	0.31 $p < 0.772$	−0.46 $p < 0.006$	−0.07 $p < 0.012$
F4-Ref	−5.45 $p < 0.041$	−1.42 $p < 0.257$	5.31 $p < 0.101$	0.78 $p < 0.202$	1.00 $p < 0.243$	0.05 $p < 0.762$	−0.00 $p < 0.654$
F8-Ref	−3.27 $p < 0.337$	1.33 $p < 0.610$	6.88 $p < 0.014$	1.52 $p < 0.004$	2.87 $p < 0.003$	1.72 $p < 0.001$	0.60 $p < 0.002$
T3-Ref	−0.53 $p < 0.688$	2.00 $p < 0.431$	5.43 $p < 0.357$	0.19 $p < 0.862$	1.48 $p < 0.074$	0.93 $p < 0.001$	0.45 $p < 0.001$
C3-Ref	0.70 $p < 0.629$	−0.35 $p < 0.520$	5.07 $p < 0.522$	0.50 $p < 0.407$	0.68 $p < 0.430$	0.08 $p < 0.707$	0.13 $p < 0.004$
Cz-Ref	−2.37 $p < 0.548$	−1.70 $p < 0.123$	7.95 $p < 0.083$	0.56 $p < 0.057$	0.89 $p < 0.149$	−0.12 $p < 0.394$	0.01 $p < 0.780$
C4-Ref	−4.11 $p < 0.095$	−2.18 $p < 0.123$	7.74 $p < 0.095$	0.69 $p < 0.065$	0.68 $p < 0.260$	0.12 $p < 0.816$	0.02 $p < 0.462$
T4-Ref	−6.29 $p < 0.005$	−3.03 $p < 0.008$	3.58 $p < 0.396$	−0.41 $p < 0.266$	0.44 $p < 0.980$	0.41 $p < 0.501$	0.63 $p < 0.089$
T5-Ref	−1.27 $p < 0.538$	0.50 $p < 0.751$	9.23 $p < 0.137$	0.65 $p < 0.121$	2.07 $p < 0.010$	0.79 $p < 0.003$	0.20 $p < 0.001$
P3-Ref	−0.80 $p < 0.545$	−1.01 $p < 0.295$	3.09 $p < 0.885$	0.22 $p < 0.783$	0.41 $p < 0.708$	0.36 $p < 0.057$	0.09 $p < 0.008$
Pz-Ref	−1.19 $p < 0.527$	−1.84 $p < 0.085$	6.59 $p < 0.521$	0.38 $p < 0.281$	0.42 $p < 0.467$	0.15 $p < 0.343$	0.03 $p < 0.334$
P4-Ref	−3.52 $p < 0.127$	−1.01 $p < 0.192$	10.26 $p < 0.099$	0.43 $p < 0.085$	0.66 $p < 0.230$	0.27 $p < 0.205$	0.06 $p < 0.040$
T6-Ref	−5.16 $p < 0.028$	0.67 $p < 0.916$	12.03 $p < 0.018$	−0.09 $p < 0.650$	0.14 $p < 0.637$	1.06 $p < 0.001$	0.33 $p < 0.001$
O1-Ref	−1.87 $p < 0.142$	0.03 $p < 0.663$	9.12 $p < 0.435$	−0.54 $p < 0.334$	−0.12 $p < 0.924$	0.41 $p < 0.016$	0.07 $p < 0.123$
O2-Ref	−3.41 $p < 0.088$	0.81 $p < 0.745$	5.72 $p < 0.513$	−0.58 $p < 0.199$	−0.63 $p < 0.315$	0.76 $p < 0.001$	0.25 $p < 0.001$

Electrode site and frequency band p values of differences in Participant 2. Positive values indicate increases and negative values indicate decreases in post evaluation percent power

Table 5 Corrected p values with the false discovery rate method for participant 2

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	0.282	0.068841176	0.095013477	0.139610837	0.139610837	0.021261905	0.283058161
Fp2-Ref	0.282	0.031789091	0.012533333	0.359488696	0.359488696	0.006778846	0.394988314
F7-Ref	0.234426829	0.003241379	0.282	0.038367347	0.038367347	0.097790323	0.011642202
F3-Ref	0.055154574	0.077931624	0.160513393	0.423641882	0.423641882	0.032883392	0.332
Fz-Ref	0.363948718	0.026908397	0.282	0.296514706	0.296514706	0.352623468	0.416452012
F4-Ref	0.282	0.417809816	0.282	0.407084261	0.407084261	0.00438342	0.070295652
F8-Ref	0.282	0.282	0.09776	0.077629213	0.077629213	0.017698745	0.282
T3-Ref	0.076542857	0.282	0.282	0.07232853	0.07232853	0.284104478	0.00564
C3-Ref	0.062666667	0.15095672	0.068212389	0.406240887	0.406240887	0.364290102	0.103152632
Cz-Ref	0.397130579	0.33621164	0.211205021	0.398609555	0.398609555	0.211352818	0.162040089
C4-Ref	0.238133333	0.401884058	0.282	0.077931624	0.077931624	0.059687117	0.003241379
T4-Ref	0.282	0.107041885	0.282	0.151444444	0.151444444	0.282	0.101729443
T5-Ref	0.024329412	0.264340509	0.282	0.281468927	0.281468927	0.16994702	0.282
P3-Ref	0.318322004	0.24436255	0.282	0.397384615	0.397384615	0.268545802	0.15035545
Pz-Ref	0.190836207	0.029573034	0.145722488	0.403178914	0.403178914	0.423	0.010493023
P4-Ref	0.190836207	0.159694382	0.282	0.151444444	0.151444444	0.172918681	0.401046549
T6-Ref	0.282	0.160600897	0.282	0.266697674	0.266697674	0.00438342	0.150657534
O1-Ref	0.364168966	0.282	0.032228571	0.314460432	0.314460432	0.030989011	0.282
O2-Ref	0.160600897	0.017698745	0.142024213	0.380128378	0.380128378	0.010493023	0.063323353

the entire time he had to pitch." On his final session (number 15) he indicated, "I am able to turn it on and off when I want now… I am able to relax between the innings and just pitch. I don't think about it—it just happens."

Participant 3 (Short Stop)

The post QEEG changes corrected for multiple comparisons included increased occipital alpha and increased beta in the central sites. There are findings of increased prefrontal power in the theta, alpha and beta frequency bands. We do not believe these findings are the result of episodic or EMG artifacts. However, there is always the possibility of and we should be sensitive to the potential of artifact contribution in the prefrontal sites. We did examine these findings visually and through quantitative measures and do not believe these findings to be a result of artifact but we recognize the sensitivity of the EEG to artifact. There is a noted decrease in slow frequency activity with maximal differences in the temporal and frontal sites bilaterally although they do not reach statistical significance (Fig. 5; Tables 6, 7).

Participant 3 was not overly communicative and was generally shy and quiet. When prompted he would report he was feeling good or tired as each day indicated. He only stated that he was happy to be participating in the study but could not articulate specific concrete examples.

Participant 4 (Pitcher)

The post QEEG changes corrected for multiple comparisons included increases of occipital theta and alpha while there were significant decreases of these frequencies in the central and temporal sites bilaterally. There were significant increases also of beta in the central, parietal and frontal sites. There was minimal to no EMG present to influence these findings (Fig. 6; Tables 8, 9).

In session 4 the participant indicated that he was aware of the brain state or the feeling that he has when he is successful at the training. He said he "is trying to put himself in that space on the field and feels as though he is more focused". Following session 11 the participant told the technician, "I am able to really focus on the glove and relax between innings". He also reported that his sleep is much improved—"I lay down and go straight to sleep".

Participant 5 (Pitcher)

The post-training QEEG analysis revealed increases of delta and significant decreases in theta and alpha in the frontal midline and central sites respectively and significant increases of beta across most electrode sites with the exception of the right frontal cortex (Fig. 7; Tables 10, 11).

Again as most participants had, this pitcher reported sleep improvements by session 8. At session 9 he stated, "I can tell a difference when I'm pitching. I'm not thinking about it and it just happens".

The CPT comparison analysis indicated a significant improvement in errors of commission ($p = 0.0255$, $t = 3.4724$). The pre-evaluation mean errors were 14.40 (SD = 10.31, SEM = 4.61) and the post-evaluation mean was 2.80 (SD = 3.56, SEM = 1.59). Response time

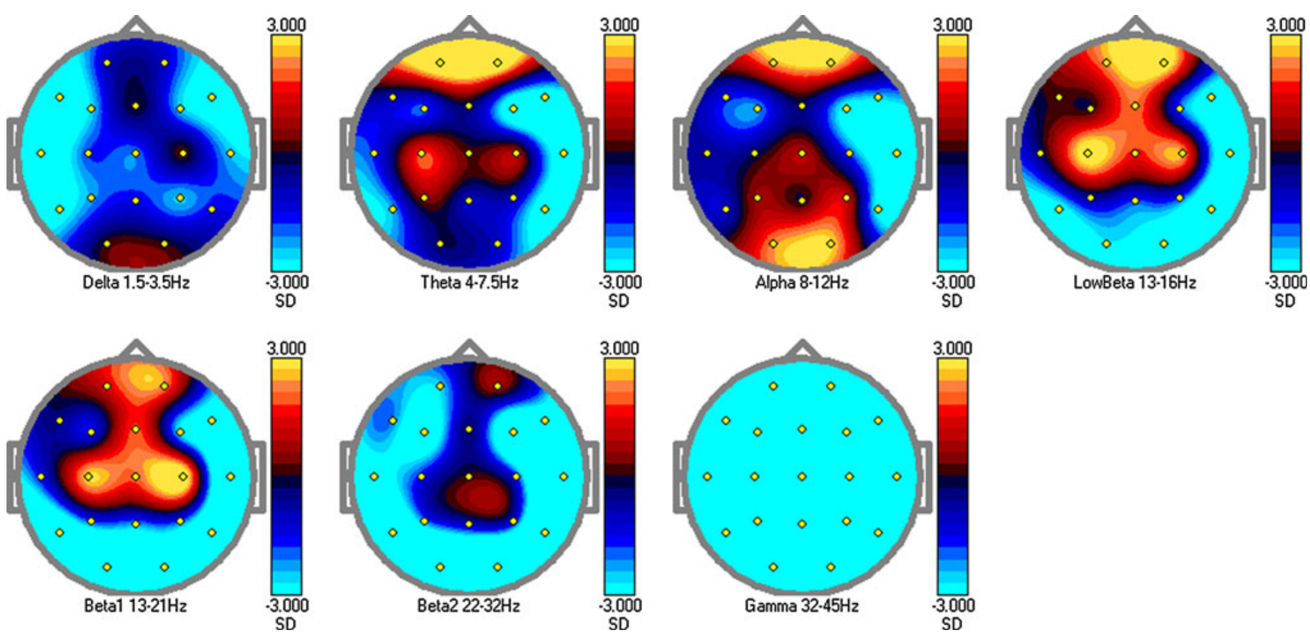

Fig. 5 QEEG topographies of Z-Score differences between pre and post evaluation of Participant 3. *Positive values* indicate increases and *negative values* indicate decreases in post evaluation percent power

Table 6 Comparison of normalized power spectra (%), normalization frequency band 0.0–64.0 Hz

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	−1.39 $p < 0.276$	3.93 $p < 0.001$	5.18 $p < 0.019$	0.80 $p < 0.024$	0.81 $p < 0.192$	−1.07 $p < 0.012$	−0.65 $p < 0.001$
Fp2-Ref	−2.07 $p < 0.230$	3.72 $p < 0.001$	5.26 $p < 0.005$	0.77 $p < 0.001$	0.88 $p < 0.034$	0.14 $p < 0.482$	−0.25 $p < 0.001$
F7-Ref	−7.64 $p < 0.001$	−0.02 $p < 0.409$	−0.72 $p < 0.129$	0.10 $p < 0.906$	0.18 $p < 0.632$	−0.32 $p < 0.047$	−0.37 $p < 0.001$
F3-Ref	−3.73 $p < 0.010$	−2.02 $p < 0.062$	−2.41 $p < 0.033$	−0.09 $p < 0.983$	−1.05 $p < 0.137$	−1.16 $p < 0.001$	−0.60 $p < 0.001$
Fz-Ref	0.35 $p < 0.981$	−0.17 $p < 0.755$	0.27 $p < 0.714$	0.50 $p < 0.039$	0.85 $p < 0.061$	−0.11 $p < 0.774$	−0.11 $p < 0.001$
F4-Ref	−2.76 $p < 0.016$	−4.70 $p < 0.001$	−4.03 $p < 0.003$	−0.28 $p < 0.057$	−1.80 $p < 0.006$	−1.51 $p < 0.001$	−0.52 $p < 0.001$
F8-Ref	−4.76 $p < 0.001$	−3.18 $p < 0.001$	−2.07 $p < 0.015$	−0.84 $p < 0.001$	−2.58 $p < 0.001$	−1.10 $p < 0.001$	−0.47 $p < 0.001$
T3-Ref	−7.25 $p < 0.001$	−0.99 $p < 0.095$	1.24 $p < 0.540$	0.34 $p < 0.678$	0.10 $p < 0.136$	−0.85 $p < 0.001$	−0.85 $p < 0.001$
C3-Ref	−2.70 $p < 0.071$	1.97 $p < 0.074$	0.55 $p < 0.757$	0.48 $p < 0.001$	0.91 $p < 0.008$	−0.33 $p < 0.129$	−0.29 $p < 0.001$
Cz-Ref	−3.10 $p < 0.048$	0.51 $p < 0.852$	3.26 $p < 0.359$	0.24 $p < 0.097$	0.77 $p < 0.048$	0.06 $p < 0.912$	−0.11 $p < 0.001$
C4-Ref	−0.07 $p < 0.885$	0.81 $p < 0.418$	−5.50 $p < 0.069$	0.34 $p < 0.023$	1.27 $p < 0.001$	−0.36 $p < 0.093$	−0.16 $p < 0.001$
T4-Ref	−2.49 $p < 0.016$	−2.66 $p < 0.001$	−7.07 $p < 0.001$	−1.41 $p < 0.001$	−5.64 $p < 0.001$	−6.10 $p < 0.001$	−2.28 $p < 0.001$
T5-Ref	−3.68 $p < 0.002$	−1.55 $p < 0.022$	−0.26 $p < 0.273$	−0.89 $p < 0.002$	−3.74 $p < 0.001$	−2.57 $p < 0.001$	−1.65 $p < 0.001$
P3-Ref	−2.48 $p < 0.027$	0.76 $p < 0.631$	4.53 $p < 0.499$	−0.09 $p < 0.453$	−0.75 $p < 0.066$	−0.45 $p < 0.029$	−0.50 $p < 0.001$
Pz-Ref	−1.37 $p < 0.132$	−0.59 $p < 0.314$	3.39 $p < 0.987$	−0.41 $p < 0.070$	−0.90 $p < 0.028$	−0.25 $p < 0.314$	−0.22 $p < 0.001$
P4-Ref	−3.05 $p < 0.017$	−0.62 $p < 0.314$	4.39 $p < 0.279$	−0.51 $p < 0.068$	−0.79 $p < 0.054$	−0.23 $p < 0.160$	−0.36 $p < 0.001$
T6-Ref	−0.54 $p < 0.121$	−3.14 $p < 0.001$	−8.32 $p < 0.003$	−1.78 $p < 0.001$	−3.20 $p < 0.001$	−2.54 $p < 0.001$	−1.31 $p < 0.001$
O1-Ref	0.70 $p < 0.933$	0.33 $p < 0.749$	8.71 $p < 0.030$	−0.90 $p < 0.007$	−3.71 $p < 0.001$	−3.76 $p < 0.001$	−2.53 $p < 0.001$
O2-Ref	1.33 $p < 0.969$	−0.41 $p < 0.254$	10.47 $p < 0.008$	−1.20 $p < 0.001$	−3.07 $p < 0.001$	−3.41 $p < 0.001$	−2.32 $p < 0.001$

Electrode site and frequency band p values of differences in Participant 3. Positive values indicate increases and negative values indicate decreases in post evaluation percent power

Table 7 Corrected p values with the false discovery rate method for participant 3

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	0.282	0.359488696	0.359488696	0.025931034	0.150837209	0.389112605	0.019567347
Fp2-Ref	0.011642202	0.025335938	0.025335938	0.282	0.329083481	0.282	0.003241379
F7-Ref	0.003241379	0.062193353	0.062193353	0.406834395	0.008095694	0.282	0.041498328
F3-Ref	0.282	0.27773535	0.27773535	0.421926941	0.305241758	0.097790323	0.229777778
Fz-Ref	0.282	0.047921569	0.047921569	0.037664384	0.398336634	0.282	0.026908397
F4-Ref	0.282	0.088027624	0.088027624	0.051519231	0.240012072	0.282	0.030288889
F8-Ref	0.314460432	0.025335938	0.025335938	0.282	0.282	0.036824742	0.087733333
T3-Ref	0.166579646	0.156950226	0.156950226	0.336612676	0.13962439	0.282	0.003241379
C3-Ref	0.282	0.134352357	0.134352357	0.282	0.07877095	0.141	0.063323353
Cz-Ref	0.282	0.406240887	0.406240887	0.077931624	0.418423493	0.239927419	0.305714808
C4-Ref	0.282	0.397092683	0.397092683	0.025335938	0.411984375	0.037664384	0.151284706
T4-Ref	0.048525974	0.311119565	0.311119565	0.282	0.305714808	0.00564	0.331911504
T5-Ref	0.282	0.39574	0.39574	0.003241379	0.282	0.282	0.357923077
P3-Ref	0.032228571	0.418661538	0.418661538	0.251964497	0.149412888	0.282	0.229561983
Pz-Ref	0.282	0.151444444	0.151444444	0.06	0.242361446	0.012533333	0.150666667
P4-Ref	0.282	0.271794286	0.271794286	0.059003077	0.00564	0.282	0.39574
T6-Ref	0.054057508	0.070293255	0.070293255	0.282	0.282	0.282	0.254799213
O1-Ref	0.282	0.265699422	0.265699422	0.009224299	0.282	0.277727273	0.413570762
O2-Ref	0.282	0.192409382	0.192409382	0.282	0.033760563	0.031789091	0.423213313

changes did not reach statistical significance at the alpha = 0.05 rate ($p = 0.099$, $t = 2.1369$), yet the response time did in fact decrease from a mean 330.20 ms (SD = 26.98, SEM = 12.06) to 312.00 ms (SD = 16.90, SEM = 7.56). Response time variability improved but was not statistically significant ($p = 0.4139$, $t = 0.9128$) with

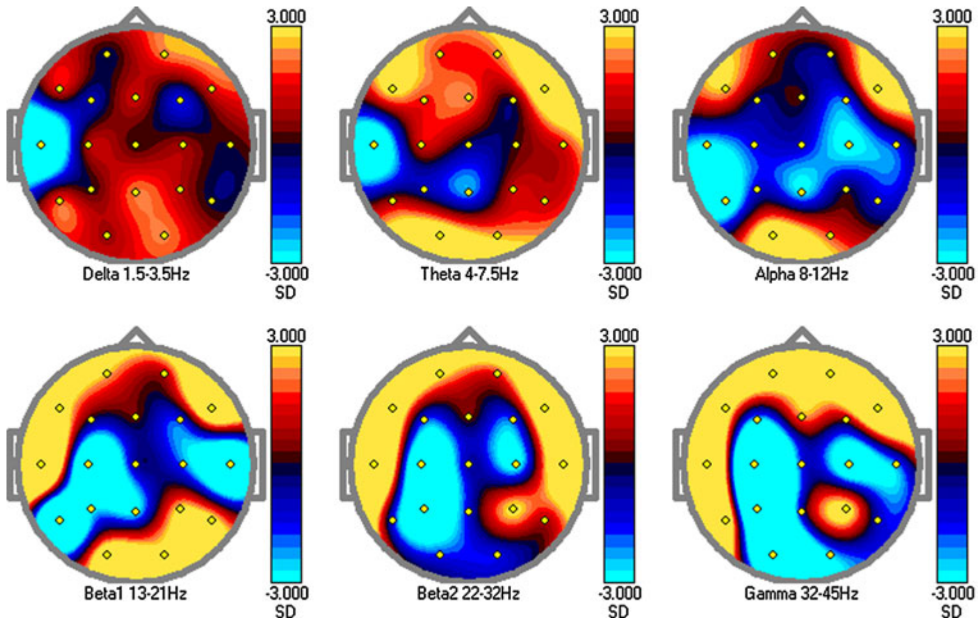

Fig. 6 QEEG topographies of Z-Score differences between pre and post evaluation of Participant 4. *Positive values* indicate increases and *negative values* indicate decreases in post evaluation percent power

Table 8 Comparison of normalized power spectra (%), normalization frequency band 0.0–64.0 Hz

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	0.03 $p < 0.830$	2.66 $p < 0.083$	1.50 $p < 0.535$	0.36 $p < 0.230$	1.25 $p < 0.009$	0.72 $p < 0.001$	0.43 $p < 0.001$
Fp2-Ref	4.84 $p < 0.032$	2.94 $p < 0.031$	0.47 $p < 0.839$	0.05 $p < 0.657$	0.46 $p < 0.284$	0.29 $p < 0.087$	0.30 $p < 0.001$
F7-Ref	1.93 $p < 0.170$	2.94 $p < 0.002$	2.72 $p < 0.009$	0.50 $p < 0.006$	1.82 $p < 0.001$	1.46 $p < 0.001$	0.48 $p < 0.001$
F3-Ref	−1.84 $p < 0.404$	2.33 $p < 0.097$	0.58 $p < 0.664$	−0.09 $p < 0.591$	0.01 $p < 0.943$	−0.31 $p < 0.139$	−0.20 $p < 0.010$
Fz-Ref	2.04 $p < 0.247$	3.65 $p < 0.025$	0.54 $p < 0.954$	0.11 $p < 0.856$	−0.02 $p < 0.818$	−0.02 $p < 0.742$	0.11 $p < 0.027$
F4-Ref	−2.20 $p < 0.172$	0.71 $p < 0.966$	−0.94 $p < 0.086$	−0.12 $p < 0.423$	−0.57 $p < 0.156$	−0.30 $p < 0.116$	0.04 $p < 0.488$
F8-Ref	2.66 $p < 0.165$	5.88 $p < 0.001$	3.67 $p < 0.001$	1.35 $p < 0.001$	3.18 $p < 0.001$	1.56 $p < 0.001$	0.71 $p < 0.001$
T3-Ref	−7.75 $p < 0.001$	−3.12 $p < 0.001$	−1.54 $p < 0.004$	0.67 $p < 0.203$	16.28 $p < 0.001$	8.95 $p < 0.001$	8.70 $p < 0.001$
C3-Ref	1.58 $p < 0.460$	1.91 $p < 0.235$	−1.59 $p < 0.139$	−0.31 $p < 0.100$	−3.79 $p < 0.001$	−1.55 $p < 0.001$	−2.97 $p < 0.001$
Cz-Ref	0.52 $p < 0.937$	−0.07 $p < 0.676$	−0.47 $p < 0.258$	−0.00 $p < 0.960$	−0.31 $p < 0.449$	−0.08 $p < 0.431$	−0.06 $p < 0.113$
C4-Ref	0.74 $p < 0.479$	0.68 $p < 0.885$	−3.39 $p < 0.002$	0.11 $p < 0.935$	−0.82 $p < 0.043$	−0.56 $p < 0.002$	−0.29 $p < 0.001$
T4-Ref	0.72 $p < 0.998$	1.22 $p < 0.145$	−0.13 $p < 0.136$	0.24 $p < 0.593$	−5.20 $p < 0.001$	19.88 $p < 0.001$	−0.26 $p < 0.041$
T5-Ref	2.44 $p < 0.079$	0.47 $p < 0.479$	−3.84 $p < 0.001$	−1.29 $p < 0.001$	−5.22 $p < 0.001$	−1.91 $p < 0.263$	4.51 $p < 0.001$
P3-Ref	0.47 $p < 0.942$	−0.35 $p < 0.435$	−1.20 $p < 0.225$	−0.16 $p < 0.222$	−0.84 $p < 0.003$	−1.39 $p < 0.001$	−1.53 $p < 0.001$
Pz-Ref	3.69 $p < 0.036$	−2.59 $p < 0.028$	−5.05 $p < 0.008$	−0.13 $p < 0.428$	−1.01 $p < 0.006$	−0.25 $p < 0.204$	−0.06 $p < 0.292$
P4-Ref	2.54 $p < 0.373$	1.31 $p < 0.252$	−1.03 $p < 0.886$	0.70 $p < 0.004$	0.93 $p < 0.004$	0.38 $p < 0.004$	0.12 $p < 0.001$
T6-Ref	−0.09 $p < 0.848$	1.08 $p < 0.254$	−2.04 $p < 0.234$	0.89 $p < 0.001$	1.48 $p < 0.001$	0.17 $p < 0.359$	−0.06 $p < 0.324$
O1-Ref	1.33 $p < 0.445$	4.49 $p < 0.001$	7.80 $p < 0.001$	1.38 $p < 0.001$	2.38 $p < 0.001$	−0.49 $p < 0.101$	−0.86 $p < 0.001$
O2-Ref	3.69 $p < 0.031$	1.89 $p < 0.015$	3.53 $p < 0.075$	0.58 $p < 0.034$	1.45 $p < 0.001$	−0.71 $p < 0.172$	−0.48 $p < 0.009$

Electrode site and frequency band p values of differences in Participant 4. Positive values indicate increases and negative values indicate decreases in post evaluation percent power

the pre-evaluation mean of 76.60 ms (SD = 23.84, SEM = 10.66) and the post-evaluation mean of 68.00 ms (SD = 10.89, SEM = 4.87). Analyses did not illustrate significant improvements in the errors of omission (two-tailed $p = 0.3739$, $t = 1.0$). This was largely due to all but one of the participants getting zero errors in the first evaluation and in the second evaluation, thus no room for improvement

The sum of the scales comprising the NeuroPerformance Profile^{TM} did show a high degree of significant change ($p = 0.0013$, $t = 8.0411$). The pre-evaluation mean of summed scales percentage points was 629 (SD = 27.93,

Table 9 Corrected *p* values with the false discovery rate method for participant 4

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	0.019567347	0.134352357	0.011642202	0.267441683	0.131458647	0.131458647	0.0144
Fp2-Ref	0.003241379	0.033760563	0.17448366	0.282	0.282	0.282	0.263930097
F7-Ref	0.041498328	0.318257143	0.282	0.282	0.048525974	0.048525974	0.044033223
F3-Ref	0.229777778	0.101936675	0.413570762	0.046229508	0.131458647	0.131458647	0.282
Fz-Ref	0.026908397	0.054436709	0.388343434	0.282	0.00438342	0.00438342	0.370573854
F4-Ref	0.030288889	0.008095694	0.114264935	0.282	0.282	0.282	0.282
F8-Ref	0.087733333	0.282	0.282	0.003241379	0.423213313	0.423213313	0.282
T3-Ref	0.003241379	0.101729443	0.282	0.282	0.282	0.282	0.282
C3-Ref	0.063323353	0.010493023	0.282	0.294510166	0.120753846	0.120753846	0.097790323
Cz-Ref	0.305714808	0.044673267	0.250233202	0.165073171	0.018721992	0.018721992	0.403742543
C4-Ref	0.151284706	0.282	0.040691275	0.012533333	0.01337069	0.01337069	0.075146132
T4-Ref	0.331911504	0.282	0.282	0.282	0.397763547	0.397763547	0.282
T5-Ref	0.357923077	0.282	0.282	0.282	0.419518519	0.419518519	0.282
P3-Ref	0.229561983	0.057801242	0.00438342	0.282	0.397928222	0.397928222	0.030288889
Pz-Ref	0.150666667	0.029573034	0.008095694	0.00564	0.28305618	0.28305618	0.190836207
P4-Ref	0.39574	0.04896463	0.00564	0.282	0.008095694	0.008095694	0.116891192
T6-Ref	0.254799213	0.282	0.282	0.282	0.142362319	0.142362319	0.282
O1-Ref	0.413570762	0.282	0.282	0.204553459	0.398171244	0.398171244	0.282
O2-Ref	0.423213313	0.282	0.282	0.00564	0.234523327	0.234523327	0.282

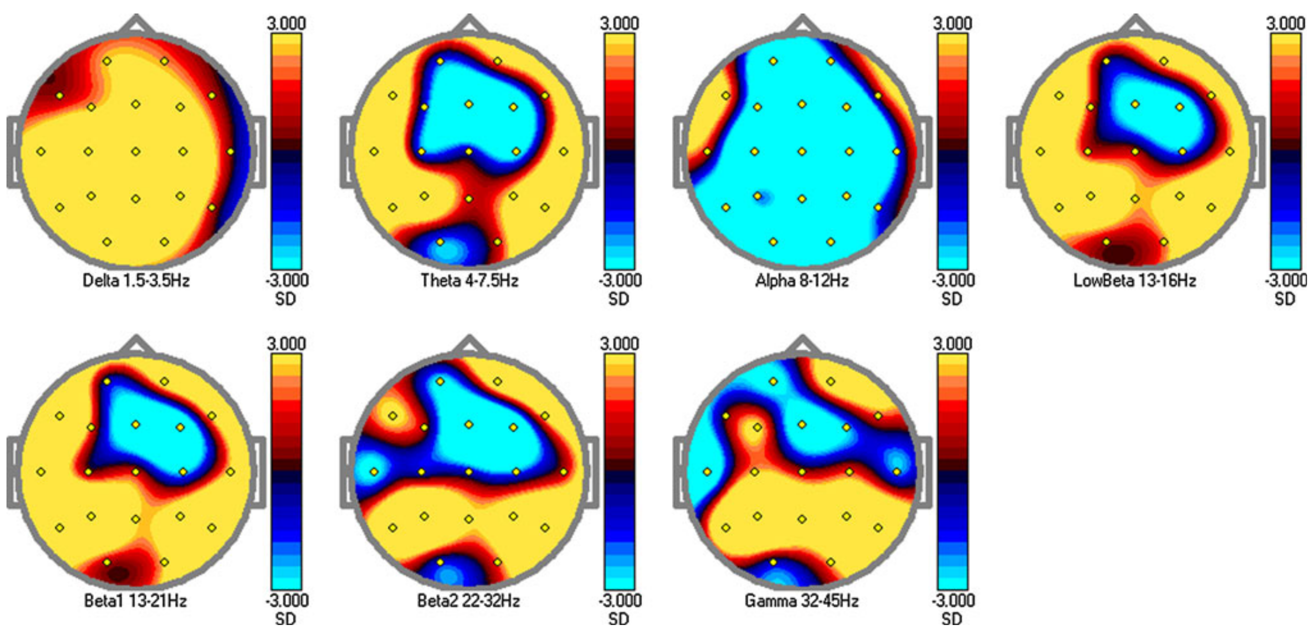

Fig. 7 QEEG topographies of Z-Score differences between pre and post evaluation of Participant 5. *Positive values* indicate increases and *negative values* indicate decreases in post evaluation percent power

SEM = 12.49) and the post-evaluation mean of summed scales percentage points was 685 (SD = 36.91, SEM = 16.51) for an improvement of 56 combined percentage points. Although some individual's NeuroPerformance Profile scales decreased, see Table 12 for specific changes, the comprehensive profile of the group demonstrated increases overall.

Discussion

The comparative findings are encouraging and suggest the further exploration of the utility of neurofeedback for populations interested in sport performance. The outcomes of this study can be characterized to the physiological

Table 10 Comparison of normalized power spectra (%), normalization frequency band 0.0–64.0 Hz

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	4.02 $p < 0.011$	−1.48 $p < 0.125$	−10.23 $p < 0.001$	0.11 $p < 0.821$	−0.25 $p < 0.496$	−0.51 $p < 0.004$	−0.19 $p < 0.001$
Fp2-Ref	3.47 $p < 0.028$	3.22 $p < 0.010$	−3.30 $p < 0.009$	1.07 $p < 0.001$	2.23 $p < 0.001$	0.55 $p < 0.001$	0.12 $p < 0.001$
F7-Ref	1.49 $p < 0.515$	7.20 $p < 0.001$	1.97 $p < 0.002$	1.62 $p < 0.001$	3.75 $p < 0.001$	−0.02 $p < 0.002$	−0.42 $p < 0.931$
F3-Ref	4.48 $p < 0.018$	−1.24 $p < 0.255$	−5.22 $p < 0.001$	0.80 $p < 0.129$	1.48 $p < 0.050$	0.07 $p < 0.391$	0.07 $p < 0.003$
Fz-Ref	6.76 $p < 0.001$	−9.43 $p < 0.001$	−14.45 $p < 0.001$	−1.38 $p < 0.001$	−3.95 $p < 0.001$	−0.82 $p < 0.001$	−0.09 $p < 0.001$
F4-Ref	5.96 $p < 0.001$	−7.88 $p < 0.001$	−11.43 $p < 0.001$	−1.76 $p < 0.001$	−4.49 $p < 0.001$	−0.76 $p < 0.001$	−0.04 $p < 0.018$
F8-Ref	1.84 $p < 0.329$	1.41 $p < 0.130$	0.79 $p < 0.620$	0.46 $p < 0.038$	1.44 $p < 0.002$	0.32 $p < 0.001$	0.05 $p < 0.078$
T3-Ref	5.70 $p < 0.001$	7.38 $p < 0.001$	0.92 $p < 0.267$	1.66 $p < 0.001$	2.15 $p < 0.001$	−2.31 $p < 0.001$	−1.83 $p < 0.001$
C3-Ref	9.03 $p < 0.001$	−1.66 $p < 0.082$	−25.27 $p < 0.001$	0.19 $p < 0.206$	0.17 $p < 0.565$	−0.10 $p < 0.321$	0.11 $p < 0.014$
Cz-Ref	4.89 $p < 0.002$	−0.84 $p < 0.358$	−7.91 $p < 0.001$	0.31 $p < 0.422$	0.89 $p < 0.264$	−0.19 $p < 0.281$	0.03 $p < 0.400$
C4-Ref	8.39 $p < 0.001$	−3.83 $p < 0.001$	−28.90 $p < 0.001$	−0.50 $p < 0.039$	−0.99 $p < 0.010$	−0.21 $p < 0.042$	0.08 $p < 0.097$
T4-Ref	0.90 $p < 0.726$	4.99 $p < 0.001$	−2.84 $p < 0.053$	0.48 $p < 0.004$	0.86 $p < 0.001$	−0.06 $p < 0.332$	−0.26 $p < 0.030$
T5-Ref	6.77 $p < 0.001$	4.78 $p < 0.001$	−16.91 $p < 0.001$	1.26 $p < 0.001$	3.00 $p < 0.001$	0.82 $p < 0.001$	0.29 $p < 0.001$
P3-Ref	7.95 $p < 0.001$	7.42 $p < 0.001$	−5.12 $p < 0.032$	1.92 $p < 0.001$	4.00 $p < 0.001$	0.91 $p < 0.001$	0.27 $p < 0.001$
Pz-Ref	6.80 $p < 0.001$	2.27 $p < 0.216$	−16.95 $p < 0.001$	0.70 $p < 0.010$	1.36 $p < 0.004$	0.34 $p < 0.003$	0.12 $p < 0.001$
P4-Ref	10.43 $p < 0.001$	4.83 $p < 0.001$	−20.59 $p < 0.001$	1.21 $p < 0.001$	2.31 $p < 0.001$	0.58 $p < 0.001$	0.17 $p < 0.001$
T6-Ref	1.29 $p < 0.286$	7.40 $p < 0.001$	−5.38 $p < 0.060$	2.10 $p < 0.001$	3.56 $p < 0.001$	0.94 $p < 0.001$	0.28 $p < 0.001$
O1-Ref	6.02 $p < 0.001$	−2.05 $p < 0.032$	−17.34 $p < 0.001$	0.20 $p < 0.520$	0.47 $p < 0.346$	−0.16 $p < 0.229$	−0.04 $p < 0.370$
O2-Ref	5.95 $p < 0.001$	1.96 $p < 0.208$	−17.74 $p < 0.001$	0.73 $p < 0.031$	1.34 $p < 0.004$	0.24 $p < 0.047$	0.08 $p < 0.009$

Electrode site and frequency band p values of differences in Participant 5. Positive values indicate increases and negative values indicate decreases in post evaluation percent power

Table 11 Corrected p values with the false discovery rate method for participant 5

	Delta 1.5–3.5 Hz	Theta 4–7.5 Hz	Alpha 8–12 Hz	LowBeta 13–16 Hz	Beta1 13–21 Hz	Beta2 22–32 Hz	Gamma 32–45 Hz
Fp1-Ref	0.282	0.00564	0.003241379	0.003241379	0.282	0.282	0.282
Fp2-Ref	0.070907514	0.282	0.282	0.282	0.282	0.282	0.282
F7-Ref	0.282	0.003241379	0.012533333	0.012533333	0.282	0.282	0.411507837
F3-Ref	0.103152632	0.228285714	0.398547812	0.398547812	0.282	0.012533333	0.00438342
Fz-Ref	0.361388601	0.282	0.070293255	0.070293255	0.282	0.028732075	0.282
F4-Ref	0.089133515	0.282	0.282	0.282	0.282	0.266697674	0.020304
F8-Ref	0.282	0.282	0.401759615	0.401759615	0.282	0.282	0.06527003
T3-Ref	0.282	0.282	0.003241379	0.003241379	0.282	0.282	0.282
C3-Ref	0.282	0.192191083	0.019567347	0.019567347	0.282	0.282	0.016588235
Cz-Ref	0.243571142	0.173776316	0.112652742	0.112652742	0.282	0.088027624	0.230204082
C4-Ref	0.003241379	0.039878788	0.0564	0.0564	0.282	0.282	0.077931624
T4-Ref	0.282	0.196689076	0.190817987	0.190817987	0.282	0.039060811	0.030989011
T5-Ref	0.164813333	0.282	0.094764228	0.094764228	0.282	0.282	0.282
P3-Ref	0.282	0.282	0.088849315	0.088849315	0.282	0.282	0.282
Pz-Ref	0.139970803	0.00438342	0.392718121	0.392718121	0.282	0.177848812	0.282
P4-Ref	0.00564	0.282	0.054057508	0.054057508	0.282	0.282	0.282
T6-Ref	0.211352818	0.282	0.139610837	0.139610837	0.282	0.193576271	0.282
O1-Ref	0.079337047	0.150531469	0.24667992	0.24667992	0.282	0.282	0.216923077
O2-Ref	0.122794937	0.044033223	0.285150838	0.285150838	0.282	0.011642202	0.011642202

changes and the decreased errors of commission on the CPT alone. However, in consideration of the positive subjective reports, the reasonable assertion that there were improvements in performance on the CPT though not all significant, and increased brain wave regulation, it seems possible that brain training may have an impact on other

Table 12 Individual participant changes in each NeuroPerformance Profile Scale

	Player 1		Player 2		Player 3		Player 4		Player 5	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Speed	439	434	400	381	378	360	400	410	399	373
Stress	292	239	334	277	389	331	281	263	405	260
Focus	353	328	362	397	371	454	350	363	396	414
AT	85	80	70	75	80	75	70	80	75	70
RS	90	90	80	80	80	75	90	90	85	75
NSp	90	90	90	80	70	75	80	80	80	80
SR	65	70	90	90	90	90	75	70	90	100
SV	70	80	65	80	70	75	70	90	70	60
NA	0	40	50	50	40	70	0	0	0	70
FE	55	50	75	90	55	95	65	70	90	80
IC	70	75	55	70	85	95	55	70	55	80
NSt	80	80	90	80	85	80	90	90	90	90
SUM Scales	605	655	665	695	655	730	595	640	635	705

Speed Speed Index, *Stress* Stress Index, *Focus* Focus Index, *AT* accuracy/timing, *RS* reaction speed, *NSp* NeuroSpeed™ Index; *SR* stress recovery, *SV* stress variability, *NA* NeuroAgility™, *FE* focus endurance, *IC* impulse control, *NSt* NeuroStrength™

domains of performance. It is worth further investigation to determine if the brain training employed in the current work may have utility in improving sport performance on the field. The QEEG patterns that changed were consistent with the noted training parameters respective to the participants. Furthermore, subjective reports were positive in nature and suggest that the participant had increased self-regulation of brain states consistent with the training protocol. The participants who were training to increase cortical arousal through inhibition of slow and increasing faster frequency bands did in fact. These participants reported increase attention and ability to focus but also recognized that this may have applicability to their sport. Those participants who were attempting to decrease cortical over-arousal and intrusive thought processes by increasing slower and mid-range frequency bands and inhibit faster frequencies did demonstrate significant percent power changes within these parameters. Additionally those participants were able to report changes in their ability to “turn it off,” “relax between innings” and to not “think about it—it just happens.” Although it wasn’t targeted as a training goal, many participants noted improvements in sleep patterns and ability to go to sleep. This finding warrants specific future investigation, as sleep characteristics are particularly important to the recovery period of a high performing athlete. The significant reduction in errors of commission indicate improvements in executive functions and impulse control and may to contribute to the participants’ abilities in other domains and future investigation should examine to what degree this may transfer to effectively perform in their sport.

The results of the current study are encouraging given the small sample size and the relatively brief number of sessions compared to the number of sessions typically completed by most professional providers of neurofeedback. In fact the study had the original hopes of being able to conduct at least 25 sessions of neurofeedback before the second evaluation. However, as is typical when working with professional sport clubs, there are many factors that influence the timetable of peripheral and secondary goals and this prevented more than 15 sessions being completed. Ideally, future research will specifically evaluate the maximally effective number of sessions. Interestingly despite this small number of sessions the QEEG showed significant changes in every participant, however some of those changes were not the targeted training frequency bands. This has been found in other studies (Cannon et al. 2010), where the training frequency bands may reflect change and yet other frequency bands and locations also show significant change. This is again an indication that is sometimes taken for granted, that the effects of targeted training often extend beyond the boundaries of our spatially precise and frequency specific neurofeedback protocols. This exploratory and brief investigation, we believe, also speaks to the potential of the training. Even with a fewer number of sessions than is typically conducted, significant changes are indicated by the QEEG. The significant findings should be interpreted cautiously since the FDR procedure yielded fewer significant findings. Significant improvements are demonstrated by one measure of the CPT and most participants reported subjective improvements. None of the participants reported any negative side effects and all appreciated the training and believed that they had benefited from the experience. Finally, a new analytic output from the EEG data, the NeuroPerformance Profile™, has been described and indicates there were changes in constructs that the authors believe to be closely tied to athlete cognitive performance.

The limitations of this study are apparent first in the sample size. As a first exploration of the specific attributes and outcomes within a professional Major League Baseball organization the results suggest the potential value of training protocols based on the Neuroperformance Profile™ and that future investigations of other professional populations are warranted. To add to this point, future studies should also consider "on the field" performance data specific to the professional sport under investigation in an attempt to evaluate the applicable value of brain training in sports enhancement. Secondly, the number of sessions that could be conducted was less than ideal and anticipated. However, it is reasonable to believe that an increased number of sessions would result in greater benefits since most investigations using neurofeedback training typically conduct an average of 32 sessions (Arns et al. 2009). The indications of improvement from this new assessment measure (the NeuroPerformance Profile™) seem sensitive to changes made by neurofeedback training; although, a large number of investigations are required to formally evaluate validity, reliability and sensitivity. Future studies would additionally examine the individual scales and indexes for change and correlate the changes as they are related to the training protocols. Because this study had a small number of overall sessions it was decided to not examine individual scale scores for change, yet there is enough evidence to compel additional studies.

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