Neurofeedback Training for Tourette Syndrome: An Uncontrolled Single Case Study

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Abstract Gilles de la Tourette syndrome (TS) is characterized by motor and vocal tic manifestations, often accompanied by behavioral, cognitive and affective dysfunctions. Electroencephalography of patients with TS has revealed reduced Sensorimotor Rhythm (SMR) and excessive fronto-central Theta activity, that presumably underlie motor and cognitive disturbances in TS. Some evidence exists that neurofeedback (NFB) training aimed at enhancing SMR amplitude is effective for reducing tics. The present report is an uncontrolled single case study where a NFB training protocol, involving combined SMR uptraining/Theta downtraining was delivered to a 17-year-old male with TS. After sixteen SMR-Theta sessions, six additional sessions were administered with SMR uptraining alone. SMR increase was better obtained when SMR uptraining was administered alone, whereas Theta decrease was observed after both trainings. The patient showed a reduction of tics and affective symptoms, and improvement of cognitive performance after both trainings. Overall, these findings suggest that Theta decrease might account for some clinical effects seen in conjunction with SMR uptraining. Future studies should clarify the feasibility of NFB protocols for patients with TS beyond SMR uptraining alone.

Keywords Gilles de la Tourette · QEEG · Neurofeedback · SMR · Theta

Introduction

Gilles de la Tourette’s Syndrome (TS) is a neurological disorder characterized by stereotyped involuntary motor and vocal tics. Motor tics appear like brief and rapid jerks of single muscles of the body (e.g., muscles of neck or face) or complex movements involving different muscles (Robertson 2000; Jankovic 2001). Vocal tics can be echophenomena such as palilalia, echolalia, echokinesis and coprolalia (Cavanna et al. 2009), typically following motor tics. Several studies have shown that tic frequency and severity increase with age (Pappert et al. 2003) and during stress or excitement (Jankovic 2001). The onset of TS ranges between the ages of 2 and 21 with a mean of 7 years, and the prevalence has been estimated around 0.3–3.8% between 5 and 18 years (Robertson 2008).

TS is frequently associated with a variety of behavioral disturbances and psychopathologies, such as attention deficit/hyperactivity disorder, anxiety, depression, and obsessive–compulsive disorder (OCD; Robertson 2000; Elstner et al. 2001; Jankovic 2001; Cardona et al. 2004; Cavanna et al. 2009). Moreover, several studies have provided evidence for cognitive impairments in TS (Middleton and Strik 2000), including deficits in psychomotor and visuo-spatial tasks, impaired inhibitory processes, poor use of metacognitive strategies and, to a lesser extent, impaired verbal fluency, planning, working memory, and cognitive flexibility (Eddy et al. 2009).

Although the pathophysiology of TS is still partially unknown, both direct and indirect evidence suggest that abnormalities in corticostriatal–thalamocortical pathways are involved in the expression of repeated, stereotyped, and unwanted movements (Mink 2001; Albin and Mink 2006) and the accompanying cognitive and emotional dysfunctions (Groenewegen et al. 2003; Singer 2005). Different tic
phenotypes would result from dysfunction of subsets of basal ganglia-thalamo-cortical circuits that do not only subserve sensorimotor and motor functions, but are also involved in cognitive, motivational and emotional processes (Utter and Bass 2008).

Besides neuroimaging methods, the recording of scalp electroencephalography (EEG) in TS has provided complementary information for the understanding of brain dysfunctions in this disorder. An altered pattern of cortical activity has been highlighted in patients with TS, including reduced Sensorimotor Rhythm (SMR, 12–15 Hz) over the sensorimotor strip (Monastra et al. 1999) and excessive frontocentral Theta (4–8 Hz; Hyde et al. 1994). SMR is initiated by reduction in efferent motor activity and afferent somatosensory input, and is suppressed during movement or imagination of a movement (Sterman and Egner 2006). The neural substrates of SMR are localized in the ventrobasal nuclei (nVB) of the thalamus, conducting afferent somatosensory information to the motor cortex. The suppression of somatosensory information and reduction in muscle tone induce a change in nVB firing patterns, shifting from non-rhythmic and fast to rhythmic and systematic bursts of discharges, that result in the appearance of SMR brainwaves (Sterman and Egner 2006). Excessive frontal Theta, consistently reported in patients with tics (Hyde et al. 1994) and motor hyperactivity (Sterman 2000), is most often associated with deficits in cognitive functions, especially attention and executive functions, and with poor impulse control (Lubar et al. 1995; Sterman 2000; Swartwood et al. 2003; Hermens et al. 2005; Banaschewski and Brandeis 2007).

Although the treatment of TS mainly consists of dopamine blocking medications in order to decrease tic frequency and severity (Robertson 2000), behavioral interventions have also been developed to enhance voluntary control over motor and vocal tics (e.g., habit reversal; see Himle et al. 2006). Given the dysfunctional EEG pattern associated with TS, Neurofeedback (NFB) is viewed as a potentially effective intervention for the treatment of this disorder. In NFB training individuals learn to self-regulate specific EEG parameters and/or patterns, e.g., the amplitude or coherence of a distinct frequency component of the EEG, through downtraining (reduction) or uptraining (enhancement) (Heinrich et al. 2007). A NFB protocol for patients with TS has been described by Tansey (1986), who reported two cases treated with SMR uptraining over the sensorimotor strip. After 14 sessions, one patient with simple motor tics was able to increase SMR amplitude 60% over baseline, and obtained a dramatic reduction of motor tics. Specifically, he reported 8 episodes of tic occurrence, from ca. 1 to over 30 min in duration, in the week preceding NFB training, and was tic-free upon training completion. The second case exhibited more complex tics such as involuntary jaw or head movements, inappropriate vocalizations, and mannerism, along with emotional and cognitive dysfunctions. The patient’s EEG showed the typical altered pattern, including reduced SMR and excessive Theta activity. After 18 sessions of SMR uptraining, SMR amplitude increased 21% over baseline and Theta amplitude decreased by 16.8%; the patient was tic-free and showed improvements in cognitive and emotional functioning. In both cases described by Tansey, the reported cessation of tic manifestations appears to be based on the patient’s accounts and the Author’s observations. No quantitative assessment of tic frequency and severity before and after NFB training was performed, e.g. by means of self-monitoring.

To our knowledge, no study has yet tested the effectiveness of combined SMR uptraining and Theta downtraining protocols for TS. Based on the acknowledged functional significance of SMR and Theta activity, and of symptoms associated with abnormalities in these cortical rhythms, it can be hypothesized that the combination of SMR uptraining and Theta downtraining could be effective for decreasing tic manifestations and improving cognitive performances involving executive functions and attention. Moreover, it can be hypothesized that behavioral and cognitive improvement would be accompanied by reduction in the severity of emotional dysfunctions.

The present uncontrolled single case study reports a SMR-Theta NFB training on a patient with TS. Motor behavior (tic frequency and severity), cognitive performance (executive functions, sustained and selective attention, lexical access), and affective status (anxiety and obsessions-compulsions) were assessed before and after training.

Methods

Participant

M.B. was a Caucasian 17-year-old male diagnosed with TS comorbid with OCD and borderline intellectual functioning (IQ = 79). He was first diagnosed with TS and OCD at age 12 by a developmental neuropsychiatrist. M.B. exhibited persistent, frequent and severe motor and vocal tics such as blowing, knocking on the table, snorting, throat clearing and swearing. He also showed attention deficits, impulsivity and distractibility.

The patient had limited participation in social and sport activities due to frequent social embarrassment caused by his tics, and had little confidence in his own social and behavioral skills. He attended secondary school with an assistant teacher due to his cognitive difficulties.

Review of the patient’s medical history failed to show any pre- and perinatal pathologies or psychomotor deficits.
He had been treated unsuccessfully with neuroleptics from age 10. During NFB training, the patient did not discontinue medication with pimozide (Orap) at the dose of 12 mg per day and sodium valproate (Depakine) at the dose of 250 mg per day.

Procedure

Written informed consent was obtained from the patient’s parents after the nature and the goal of the NFB protocol had been fully explained. The patient provided assent to intervention.

Quantitative EEG (QEEG) recordings in rest condition, and cognitive and affective evaluations were performed at pre-training and at re-evaluations.

Physiological Recording

QEEG assessment and NFB sessions were carried out employing ProComp Infiniti (Thought Technology Ltd, Montreal, QC) hardware and software. Gold electrodes were applied with paste on three central sites over the motor strip (Cz, C3 and C4) according to the International 10–20 System (Jasper 1958), with reference on the left earlobe and ground on the right one. Impedance was kept below 5 KOhm.

In order to correct muscle artifacts and eye movements, the electromyogram (EMG) and the electroculogram (EOG) were recorded. The raw EMG signal was recorded from the left mid-forearm with a 2,048 Hz sampling rate, and then rectified and integrated on-line. The EOG was sampled at 256 Hz using gold cup electrodes placed below and at the outer canthus of the left eye in order to detect vertical and horizontal eye movements.

The EEG signal was sampled at 256 Hz. The digitized waveforms were edited off-line in order to remove segments containing muscle artifacts and eye movements. Each QEEG assessment included two 3-min blocks of eyes-open EEG recording. Using the BioGraph Infiniti software (Thought Technology Ltd, Montreal, QC), a series of digital filters were applied to the recorded signal to extract frequency-domain information. After passing data through a Hanning window, spectral power estimates were calculated for each active site on raw 1-s EEG segments (1-Hz frequency resolution). Then, power values within the SMR (12–15 Hz), Theta (4–8 Hz), Alpha (8–12 Hz), Delta (1–4 Hz), and Beta (15–30 Hz) bandwidths were averaged across consecutive 10-s segments.

All QEEG assessment sessions were performed at approximately the same time of the day. The patient was seated in a comfortable armchair and then electrodes were applied. Before starting the recording, the experimenter asked the patient to remain as quiet as possible for the entire recording duration.

Neurofeedback Training

NFB sessions took place twice per week at the same time of the day.

Each session consisted in 3-min eyes-open baseline recording followed by five 3-min periods, each including 150 s of feedback and 30 s of “blink break” (as described in Vernon et al. 2003).

The raw EEG signal was band-filtered online to extract SMR (12–15 Hz) and Theta (4–8 Hz) band. The patient had to simultaneously increase SMR amplitude and decrease Theta amplitude over Cz. Feedback thresholds were set on SMR and Theta average amplitudes over the 3-min resting eyes-open baseline recordings. The feedback consisted of a pleasant sound provided whenever the patient was able to achieve the desired condition. Furthermore, credit points were given as a reward whenever the target condition was maintained for at least 250 ms. Feedback delivery was inhibited when eye movements caused gross EEG fluctuations or when forearm muscle activity increased.

After sixteen sessions of SMR-Theta training, due to the patient’s difficulty to achieve a significant SMR increase over all three recording sites (see “Results”), six additional sessions were focused only on SMR uptraining, which has been reported as an effective protocol in the literature (Tansey 1986). However, Theta activity was monitored during this second training as well.

Clinical Evaluation

The patient was explained how to fill out a self-monitoring diary to record the frequency (total number per day) and subjective severity (0–10 range, with higher scores indicating greater severity) of obscene and non-obscene vocal and motor tics. Ratings were collected 3 days per week, for 2 weeks, before and after the first training. Unfortunately, the patient reported that after the second training he recorded the ratings with poor accuracy, and therefore those data have not been considered reliable for analysis.

The patient’s cognitive functioning was assessed before treatment and after each training by a trained clinical psychologist who was not involved in the NFB protocol. The following tests, selected from The Neuropsychological Battery for adolescence (BVN 12–18; Gugliotta et al. 2009), were used:

1. **Selective Acoustic Attention task** assesses selective and sustained attention and inhibition skills. It requires the subject to beat the hand on the table every time a target
word (e.g., “Sun”) is read. Scores range from 0 to 45, with higher scores indicating better performance. Test–retest reliability with a 15-day interval is very high ($r = 0.96$). Also, this task has been shown to have significant convergent validity with verbal IQ as measured by the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler 1974) and with the Peabody Picture Vocabulary Test (Dunn and Dunn 1981; Italian version by Stella et al. 2000) ($r = 0.467$ and 0.465, respectively).

2. **Selective Visual Attention Task** evaluates visual scanning, sustained attention and inhibition of inappropriate responses. It requires subjects to recognize and then to erase with a pen all the targets (the number “21” in a square with internal lines on the upper side and on the right angle) among distractors. Scores range from 0 to 21, with higher scores indicating better performance. Test–retest reliability with a 15-day interval is moderate ($r = 0.50$).

3. **Tower of London Test** (Shallice 1982) investigates problem-solving ability and strategic planning processes. It requires to modify the initial configuration of 3 colored balls on 3 pivots of different length to get 12 different configurations. Scores for performance accuracy range from 0 to 12, with higher scores indicating better performance. Test–retest reliability with a 7–10-day interval is moderate ($r = 0.57$). Also, this test has shown significant discriminant validity between youth with typical and atypical development.

4. **Phonemic Verbal Fluency Test** investigates lexical access and strategic search processes. Subjects are required to generate as many words as they can beginning with a specified consonant (e.g., C, S and P), within the time-limit of 1 min for each letter. The number of words generated in 1 min for each letter is recorded, and the score is the total number of words generated in the 3 min. Higher scores indicate better performance. Test–retest reliability with a 15-day interval is high ($r = 0.80$). Also, this task has been shown to have significant convergent validity with verbal IQ as measured by the WISC-R (Wechsler 1974) ($r = 0.386$).

5. **Categorical Fluency Task** measures executive functions and frontal lobe functioning. Subjects are required to name words of a particular semantic category (Colors, Animals, Fruits and Cities), within the time-limit of 1 min for each category. The number of words generated in 1 min for each category is recorded, and the score is the total number of words generated in the 3 min. Higher scores indicate better performance. Test–retest reliability with a 15-day interval is high ($r = 0.78$). Also, this task is reported to have significant convergent validity with verbal IQ as measured by the WISC-R (Wechsler 1974) and with the Peabody Picture Vocabulary Test (Dunn and Dunn 1981; Italian version by Stella et al. 2000) ($r = 0.668$ and 0.660, respectively).

The patient’s affective status was evaluated by administering self-report instruments selected from the *Psychiatric Self evaluation Scale for Children and Adolescents—SAFA scale* (Cianchetti and Sannio Fancello 2001) in order to assess anxiety, obsessive–compulsive and somatic symptoms:

1. **Anxiety symptoms self-evaluation scale (SAFA-A)** is a 50-item scale divided into 4 subscales assessing generalized, social, separation and school-related anxiety. Total score ranges from 0 to 100, with T scores higher than 60 indicating pathological anxiety symptoms for both the total scale and the 4 subscales. Test–retest reliability with a 15-day interval is very high ($r = 0.87$); internal consistency is also very high (Cronbach’s alpha coefficient = 0.94). Also, the SAFA-A is reported to have good convergent validity with the IPAT Anxiety Scale Questionnaire (Cattell and Scheier 1963; Italian version by Novaga and Pedon 1979) ($r = 0.602$ in healthy youths, and $r = 0.897$ in youths with anxiety disorders), and highly significant discriminant validity between healthy and anxious youths.

2. **Obsessive–compulsive symptoms self evaluating scale (SAFA-O)** is a 38-item scale that assesses obsessive thoughts, compulsions and rituals, rupophobia and contamination, order and control, and doubt and indecision. Total score ranges from 0 to 76, with T scores higher than 60 indicating pathological obsessive–compulsive symptoms for both the total scale and the 5 subscales. Test–retest reliability with a 15-day interval is very high ($r = 0.93$); internal consistency is adequate (Cronbach’s alpha coefficient = 0.63). Also, the SAFA-O has been shown to have highly significant discriminant validity between healthy individuals and patients with obsessive–compulsive disorder.

3. **Somatic symptoms and Hypochondria self evaluating scale (SAFA-S)** is a 25-item scale that assesses cardiac, gastrointestinal and respiratory symptoms, asthenia, sleep and general cenesethesis. It can be divided into 2 subscales, somatic symptoms and hypochondria. Total score ranges from 0 to 50, with T scores higher than 60 indicating pathological somatic and hypochondria symptoms, for both the total scale and the 2 subscales. Test–retest reliability with a 15-day interval is very high ($r = 0.92$); internal consistency is high (Cronbach’s alpha coefficient = 0.80). Also, the SAFA-S is reported to have highly significant discriminant validity between healthy individuals and patients with obsessive–compulsive disorder.
validity between healthy individuals and patients with somatoform disorder, depression, or anxious-depressive disorder.

Statistical Analysis

SMR and Theta power values were calculated for the pre-training and for the two re-evaluations, namely after concurrent SMR uptraining-Theta downtraining and after SMR uptraining alone. Separate repeated-measures ANOVAs were conducted on SMR and Theta power values, with factors Electrode (C3, Cz and C4) and Time (Pre-training, First re-evaluation, Second re-evaluation).

The significance of main effects and interactions was adjusted with the Greenhouse-Geisser method to correct conservatively for violations of sphericity. In the results, the corrected p levels and epsilon (\(\varepsilon\)) are reported together with the uncorrected degrees of freedom. Bonferroni post-hoc tests, which correct for multiple comparisons, were performed when appropriate. Statistical analyses were performed using STATISTICA 6.1 software (StatSoft, Inc.; Tulsa, OK).

All scores obtained in the cognitive tests and on questionnaires were converted to \(z\) scores \(\frac{(\text{raw score}-\text{mean score})}{\text{standard deviation}}\). Results were interpreted by comparing the patient’s scores with normative data.

The frequency and severity of motor and vocal tics before treatment and after the first training were calculated as the mean of the recorded values over each monitoring period. Percent improvement was calculated according to the following formula: \(\frac{(\text{pre-training} - \text{post-training})}{\text{pre-training}}\)\(^*100\). Improvements greater than 50% were considered clinically significant (Blanchard and Andrasik 1987).

Results

SMR and Theta

The analysis performed on SMR power revealed a significant main effect of Electrode \((F(2, 70) = 9.72; p = 0.0004; \varepsilon = 0.85)\). Post-hoc comparisons indicated significantly greater power at Cz as compared with both C3 \((p = 0.0001)\) and C4 \((p = 0.012)\). SMR power at C3 was not significantly different from that at C4.

The significant Electrode \(\times\) Time interaction \((F(4,140) = 16.37; p = 0.0001; \varepsilon = 0.74)\) clarified that SMR power at Cz significantly increased from the pre-training to the second re-evaluation \((p = 0.004)\). SMR power at C3 was significantly greater at the first and second re-evaluations (not differing from each other) as compared with the pre-training \((p = 0.013\) and 0.002, respectively). At C4, the time course of SMR power changes included a decrease from the pre-training to the first re-evaluation \((p = 0.0001)\), and a return to pre-training values at the second re-evaluation.

With regard to Theta power, a significant main effect of Electrode was found \((F(2, 70) = 231.6; p = 0.0001; \varepsilon = 0.81)\), with post-hoc comparisons indicating larger Theta power at Cz as compared with both C3 and C4 \((ps = 0.0001)\). Theta power at C3 was not significantly different from that at C4.

The significant Electrode \(\times\) Time interaction \((F(4,140) = 21.7; p = 0.0001; \varepsilon = 0.49)\) indicated that Theta power at C4 significantly decreased from the pre-training to the first and second re-evaluations \((ps = 0.0001)\). No significant change in Theta power emerged at C3 and Cz.

Figure 1 shows SMR power at Cz (top) and Theta power at C4 (bottom) at the pre-training, first and second re-evaluations.

Clinical Evaluation

Overall, the frequency and the severity of all categories of motor and vocal tics decreased from the pre-training to the first re-evaluation (see Table 1). The reduction was clinically significant for the frequency of non-obscene vocal tics and frequency and severity of obscene motor tics.

Scores on all cognitive tests were out of normative range at pre-training. Upon treatment completion, the patient’s scores for Tower of London and Phonemic Verbal Fluency had significantly improved and fell within normative range.
Selective Acoustic and Visual Attention and Categorical Fluency also improved, although they remained out of normative range.

At pre-training, SAFA-A total score, and subscale scores for generalized, social, separation and school-related anxiety were out of normative range. The same was true for SAFA-O scores of obsessions and compulsions, rituals, doubt and indecision, and for SAFA-S somatic symptoms subscale scores.

Upon treatment completion, all scores had fallen within normative range. Clinical improvement was progressively obtained throughout the treatment period, with several variables showing significant improvement already after the concurrent SMR-Theta training.

Table 2 displays all cognitive and affective scores at pre-training and first and second re-evaluations.

**Discussion**

The present manuscript reports the outcomes of a NFB protocol to treat symptoms in a patient with TS. To our knowledge, existing accounts of NFB protocols for TS have been focused on SMR uptraining alone (Tansey 1986), thus leaving the effectiveness of combined SMR uptraining and Theta downtraining untested. Because excessive frontal Theta is most often associated with deficits in cognitive functions, especially attention and executive functions (Lubar et al. 1995; Sterman 2000; Swartwood et al. 2003; Hermens et al. 2005; Banaschewski and Brandeis 2007), we hypothesized that concurrent SMR uptraining and Theta downtraining could be more effective than SMR uptraining alone for decreasing tic manifestations and improving cognitive performance, respectively.
In the present uncontrolled single case study we observed that, overall, both SMR and Theta power values were greater at Cz as compared with C3 and C4. Symmetrical activity at C3 and C4 is most probably due to the fact that both EEG rhythms originate in the thalamus, whereas activity at Cz reflects a wider range of both thalamic and cortical influences (Sterman 1996; Sterman and Egner 2006).

When SMR and Theta were trained simultaneously, both SMR and Theta power changed in the desired direction, but this effect was only significant at one site, namely, C3 for SMR and C4 for Theta. Therefore, when the training involved concurrent SMR uptraining and Theta downtraining, significant SMR increases with respect to the pre-training were confined to only one site over the sensorimotor strip. On the other hand, when SMR uptraining was administered alone the resulting significant increase in SMR power with respect to the first re-evaluation was more general, encompassing C3, Cz, and C4 (at this latter site SMR power returned to pre-training values after a substantial decrease from pre-training to the first re-evaluation). It is worth noting that the increase in SMR power after SMR-only training was accompanied by further significant reduction in Theta power at C4. The topography of these effects is an issue that future studies employing multiple EEG recording sites should explore in more detail, in order to clarify its functional significance.

Our finding of additional Theta power decrease after the second training, that did not involve Theta downtraining, suggests that changes in Theta power might be easier to achieve and/or to maintain compared to SMR, even when a complex training protocol (namely, concurrent control of both SMR and Theta) is used. Alternatively, it is possible that the decrease in Theta power occurred not only as a direct outcome of NFB training specifically aimed at modifying Theta activity, but also as a secondary, non-specific result of the patient having to concentrate his attention on the training task. In fact, Theta power remained significantly reduced as compared to the pre-training even after the training was aimed at modifying only SMR. Along the same line of reasoning, the amelioration in the patient’s clinical symptoms we observed both after combined SMR-Theta and after SMR-only trainings suggests that clinical improvement after SMR-only training reported in the literature (Tansey 1986) might, at least partially, derive from a more general attentional improvement associated with Theta reduction.

On a different perspective, the results of the present uncontrolled single case study might imply that increasing SMR and reducing Theta activity were more difficult for the patient to achieve simultaneously, or that learning voluntary control of SMR and Theta power might entail different time spans, namely, shorter for Theta than for SMR. In fact, previous research indicates that SMR uptraining requires a larger number of sessions as compared with Theta downtraining (Demos 2005).

The present results support the existing limited literature by demonstrating that, overall, NFB training has tangible effects on the ability of patients with TS to engage in daily activities. Indeed, upon treatment completion the patient succeeded in performing independently a number of activities he was unable to carry out before treatment, such as using public transport, having a meal at a restaurant, making a phone call, and paying attention during school lessons. In addition, a concurrent reduction of anxiety, obsessive and compulsive symptoms was associated with decreased tic frequency and severity and improvement in cognitive performance.

There are some limitations to be recognized in interpreting our data. The differential effectiveness of SMR-only or Theta-only NFB trainings remains to be clarified, and clinical assessment of their effects should include instruments and tasks aimed at specifically evaluating cognitive and behavioral abilities related with SMR and Theta activity (e.g., Go/No-Go task, task switching, dual task, finger tapping test). Moreover, the duration of the combined SMR-Theta training should be extended, in order to clarify whether simultaneous control of both rhythms can be learnt after prolonged training. A further limitation is that follow-up data to test for long-term retention of the obtained clinical outcomes were not available. Multiple pre-training QEEGs, a larger number of patients, and controlled studies should be also carried out in order to fully estimate the possible effectiveness of such NFB intervention.

In conclusion, the present uncontrolled case study provides evidence of the effectiveness of NFB intervention in treating tic manifestations and cognitive deficits in TS. Our results may lead to the development of more effective treatments for TS that involve training single or multiple EEG frequency bands.

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