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Effects of Neurofeedback on Adult Patients with Psychiatric Disorders in a Naturalistic Setting

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Abstract Few well-controlled studies have considered neurofeedback treatment in adult psychiatric patients. In this regard, the present study investigates the characteristics and effects of neurofeedback on adult psychiatric patients in a naturalistic setting. A total of 77 adult patients with psychiatric disorders participated in this study. Demographic data and neurofeedback states were retrospectively analyzed, and the effects of neurofeedback were evaluated using clinical global impression (CGI) and subjective self-rating scales. Depressive disorders were the most common psychiatric disorders (19; 24.7 %), followed by anxiety disorders (18; 23.4 %). A total of 69 patients (89.6 %) took medicine, and the average frequency of neurofeedback was 17.39 ± 16.64. Neurofeedback was applied to a total of 39 patients (50.6 %) more than 10 times, and 48 patients (62.3 %) received both β/SMR and α/θ training. The discontinuation rate was 33.8 % (26 patients). There was significant difference between pretreatment and posttreatment CGI scores (<.001), and the self-rating scale also showed significant differences in depressive symptoms, anxiety, and inattention (<.001). This is a naturalistic study in a clinical setting, and has several limitations, including the absence of a control group and a heterogenous sample. Despite these limitations, the study demonstrates the potential of neurofeedback as an effective complimentary treatment for adult patients with psychiatric disorders.

Keywords Neurofeedback · Adult psychiatric patient · Depression · Anxiety

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Introduction

There are two conventional treatment modalities in psychiatry: pharmacological treatment and psychotherapy. Pharmacological treatment employs drugs to reduce psychiatric symptoms, and its effectiveness varies across disorders and medications. Antidepressant medications, when used as a monotherapy in placebo-controlled registration trials, typically result in 30–35 % remission rates (Rush et al. 2011). Psychotherapy includes psychodynamic psychotherapy and cognitive behavioral therapy. The effect of cognitive behavioral therapy is similar to that of pharmacotherapy, although the effect size is small (Lynch et al. 2010). Psychodynamic psychotherapy shows empirical effectiveness, although there is some difficulty in verifying it through experimental studies (Cuijpers et al. 2008). However, there is an unmet need for such conventional treatment methods. Pharmacological treatment methods can lead to adverse outcomes such as dry mouth, headache, nausea, constipation, and sexual dysfunction, which can hamper the patient's treatment compliance and quality of life (Lam et al. 2009). To enhance treatment effectiveness

and address the limitations of conventional methods, many complementary treatments have been proposed, among which neurofeedback is one of the most sophisticated method.

EEG biofeedback, known as neurofeedback, is an operant conditioning procedure in which patients learn to improve the brain's functional activity (Larsen and Sherlin 2013; Weiskopf et al. 2004). It is an active training program in which the individual can restore the regulation of the brain network, spontaneously (Johnston et al. 2010; Weiskopf et al. 2004). Since 1960, neurofeedback has been verified to be effective in epilepsy and applied to various fields. In addition, its potential to be used to elucidate the mechanisms underlying psychopathology by evaluating the subjective effect of the modulation of specific brain areas has become apparent (Linden et al. 2012; Moriyama et al. 2012; Sterman et al. 1974). In psychiatry, neurofeedback has been used in attention deficit hyperactivity disorder (Moriyama et al. 2012), depressive disorders, anxiety disorders (Hammond 2005), sleep disorders (Arns and Kenemans 2014; Cortoos et al. 2009), substance abuse (Sokhadze et al. 2008), the cognitive rehabilitation of patients with head trauma or cerebrovascular disorders (Angelakis et al. 2007; Thornton 2000). In addition, it has been used to improve performance (peak performance) in normal individuals (Vernon 2005).

There is sufficient evidence supporting neurofeedback treatment in epilepsy (Sterman et al. 1974), attention deficit hyperactivity disorder, and substance abuse (Moriyama et al. 2012; Sokhadze et al. 2008), but few well-controlled studies have considered neurofeedback treatment in adult psychiatric patients. In this regard, the present study investigates the characteristics and effects of neurofeedback on adult psychiatric patients in a naturalistic setting.

Materials and Methods

Participants

The participants were enrolled from a population of patients with neurofeedback treatment at an outpatient clinic of the psychiatric department of a university hospital from August 2005 to August 2009. A total of 77 adult patients whose ages exceeded 18 were recruited. For inclusion in the study, patients had to meet DSM-IV-TR criteria for Axis I disorder (American Psychiatric Association and American Psychiatric Association Task Force on DSM-IV 2000). They could communicate with the evaluator and consented to participate in neurofeedback training. Patients with low tolerability with medications or unsatisfactory treatment response were regarded suitable candidate. Patient with dementia, mental retardation, head trauma, epilepsy, and other organic mental disorders were excluded from the study.

Experimental Procedure

Patients who met inclusion and exclusion criteria of the study were referred to the neurofeedback clinic by the attending psychiatrist. The patients were evaluated during weekly neurofeedback team meetings with three psychiatrists and a neurofeedback therapist. The neurofeedback protocol was determined by psychiatrists certified in neurofeedback during the neurofeedback team meeting for each patient. This decision took into account the patient's chief complaints, opinions of the attending psychiatrist at the outpatient clinic, neuropsychiatric evaluation results, and the subjective-symptom-rating scale. Outcomes of neurofeedback treatment were reviewed by the psychiatrist specializing in neurofeedback, and feedback was provided to each patient. In addition, an appropriate treatment protocol was arranged as needed. As a retrospective study, patient consent was exempted, and this study was approved by the hospital ethics committee.

Measures

Demographic data, the patient's psychiatric history, and the neurofeedback training protocol were recorded. The primary measure of treatment effectiveness was the clinical global impression-severity (CGI-S) scale, which is a widely used tool in the objective rating of treatment effectiveness. It is rated on the following seven-point scale: 1 = normal, not at all ill; 2 = borderline mentally ill; 3 = mildly ill; 4 = moderately ill; 5 = markedly ill; 6 = severely ill; 7 = among the most extremely ill patients. The CGI can track clinical progress across time and has been shown to correlate with longer, more tedious and time consuming rating instruments across a wide range of psychiatric diagnoses. It has shown good inter-rater reliability and validity, and recently published guidelines improved the precision of CGI scoring (Busner and Targum 2007; Busner et al. 2009). The CGI ratings were determined during weekly neurofeedback team meetings with attending psychiatrists from the outpatient clinic and those psychiatrists in charge of the initial planning and supervising the progress of neurofeedback treatment and we found significant inter-rater correlation (Kappa $> .90$).

The secondary measure of treatment effectiveness was the Hill–Castro checklist for the subjective rating of symptom improvement. For the patient's better understanding, the visual analog scale (VAG) was adopted. This checklist includes the following psychiatric symptom categories: depression, anxiety, hostility, sleep, impulsivity, hyperactivity, attention, self-esteem, immaturity,

masochism, and tic, and others. The checklist provides percentages, not cutoff scores, and a broader overview of how a patient is functioning in various areas of his or her life (Hill and Castro 2002).

Neurofeedback Apparatus

The neurocybernetics model of neurocybernetics company was used for neurofeedback training. The brain's electrical activity was displayed on a monitor in the form of an audiovisual exercise. In the SMR or beta training protocol, the patients were introduced a computer game, and reward feedback was represented as achievement scores and graphs during and after training. In the alpha-theta training protocol at the Pz area, the patients sat in a chair with eyes closed, and only audio feedback was provided. In SMR training, the reward band ranged from 12 to 15 Hz, and in beta training, from 15 to 18 Hz. In alpha-theta training, the patients were trained simultaneously to reduce alpha and increase theta to the point at which they 'crossed over', which was defined as the point at which the alpha amplitude dropped below the level of theta (Dehghani-Arani et al. 2013). The theta (5–8 Hz) and alpha (8–12 Hz) were reward bands. Before and during training, the participants were instructed to develop the most successful mental strategy to get as much reward feedback as possible.

Statistics

A frequency analysis and a technique analysis were conducted to examine the patients' demographic characteristics and clinical features. To examine the effect of neurofeedback on the patients, a paired t test was conducted based on changes in pre-treatment and post-treatment CGI scores as an objective index and on changes in the Hill–Castro checklist as a subjective index, setting time as a covariant. PASW version 18.0 for Windows (Chicago, IL) was used for all statistical analyses. The level of significance in each analysis was set to .005 with Bonferroni correction procedure.

Results

Demographic Data and Clinical Characteristics

Table 1 summarizes the demographic data and clinical characteristics of the sample. Among the 77 patients, 40 (51.9 %) were male. The patients' ages were evenly distributed, with 36 (46.8 %) in their thirties and forties (the largest age group).

The patients received neurofeedback for depressive disorders, anxiety disorders, sleep disorders, somatoform disorders, adjustment disorders, bipolar disorder, schizophrenia, attention deficit hyperactivity disorder, alcohol dependence, game addiction, and impulse control disorder. The most common diagnosis included was depressive disorders (24.7 %), followed by anxiety disorders (23.4 %). Anxiety disorders included generalized anxiety disorder, panic disorder, obsessive–compulsive disorder, social phobia, acute stress disorder, and posttraumatic stress disorder. The duration of illness ranged from <2 to >6 years. Most of the patients (89.6 %) currently received psychiatric pharmacological treatment, and the duration of treatment ranged from <2 to >4 years.

Neurofeedback Treatment State

Table 2 shows the neurofeedback treatment protocol. The average frequency of neurofeedback treatment was 17.39 ± 16.64. A total of 39 patients (50.6 %) received neurofeedback treatment more than 10 times. A total of 26 patients received less than 5 sessions. The patients belongs to the group, who took 6–10 sessions of treatment, were 9, 11–15 sessions were 8, 16–20 sessions were 6. The patient who received more than 20 sessions of treatment was 25. The neurofeedback protocol was beta, sensorymotor rhythm (SMR), and/or alpha-theta training. The protocol combining alpha-theta training with either beta or SMR training was the most common method (62.3 %). The regions of the brain where neurofeedback was applied to were Fp1, Fp2, F3, F4, F7, F8, T3, T4, C3, C,4, P1, P2, O1, O2, and Oz based on the international 10–20 EEG system (Herwig et al. 2003). A total of 49 patients (63.6 %) were treated in more than two brain regions. The discontinuation rate for neurofeedback treatment was 33.8 %. The discontinuation was defined as ending therapy without prescription of attending psychiatrist or lost to follow up.

In this study, the neurofeedback protocol was not uniform according to the diagnosis. For example, in those patients with depressive disorders, their chief complaints ranged from anxiety, agitation, and emotional unstability to lethargy, reduced energy, concentration difficulties, and thought distortion. The treatment protocol was adjusted according to each patient's chief complaints, the treatment goal of the attending psychiatrist, and outcomes for the subjective-symptom-rating scale. In those patients with anxiety disorders, alpha–theta training was chosen, and an individualized protocol was selected during the neurofeedback meeting. Those patients showing a low threshold for anxiety were treated with SMR training at T4 and alpha-theta training at Pz at first. When their anxiety level decreased after neurofeedback treatment, beta training was introduced at F3. In sum, the treatment protocol was individualized and finalized during weekly neurofeedback meetings.

Table 1 Demographic data and clinical characteristics (n = 77)

Variables	Groups	N (%)
Sex	Male	40 (51.9)
	Female	37 (48.1)
Age (mean ± SD)	10's to 20's	24 (31.2)
	30's to 40's	36 (46.8)
	50's to 6o's	13 (16.9)
	70's to 80's	3 (3.9)
	39.86 ± 15.46	
Education (mean ± SD)	Years ≤ 9	7 (9.1)
	9 < years ≤ 12	29 (37.7)
	Years > 12	36 (46.8)
	13.78 ± 2.70	
Diagnosis	Depression	19 (24.7)
	Anxiety disorder	18 (23.4)
	Sleep disorder	8 (10.4)
	Somatoform disorder	6 (7.8)
	Adjustment disorder	5 (6.5)
	Bipolar disorder	4 (5.2)
	ADHD	3 (3.9)
	Game addiction	3 (3.9)
	Psychosis	3 (3.9)
	Other psychiatric disorders	6 (7.8)
Duration of illness (years)	Years ≤ 2	32 (41.6)
	2 < years ≤ 4	34 (44.2)
	4 < years ≤ 6	4 (5.2)
	Years > 6	4 (5.2)
Presence of medication	Presence	69 (89.6)
	Not presence	7 (9.1)
Duration of medication (years)	Years ≤ 2	35 (45.5)
	2 < years ≤ 4	18 (23.4)
	Years > 4	16 (20.8)

Table 2 States of EEG biofeedback

Variables	Groups	N (%)
Frequency (mean ± SD)	Total	74 (17.39 ± 16.64)
	1–5	26 (2.73 ± 1.28)
	6–10	9 (7.56 ± 1.33)
	11–15	8 (13.13 ± 1.25)
	16–20	6 (17.50 ± 1.64)
	>20	25 (37.52 ± 11.89)
Protocol	β/SMR	6 (7.8)
	α/θ	19 (24.7)
	Both β or SMR and α/θ	48 (62.3)
Region	Only one region	23 (29.9)
	Over two regions	49 (63.6)
Discontinuation rate		26 (33.8)

Neurofeedback Effectiveness by CGI Scores

The average pre-treatment CGI score was 2.99 ± 1.54, and the average post-treatment CGI score was 1.88 ± 1.57. There were significant decreases in the severity of symptoms after treatment (<.001).

Neurofeedback Effectiveness by the Hill–Castro Checklist Score

Figure 1 and Table 3 show the pre-treatment and post-treatment Hill–Castro checklist scores. The Hill Castro Checklist score was given to all the patients who received neurofeedback treatment at baseline and the end of the treatment. Only 22 patients were responded both at baseline and the end of the treatment. There were significant improvements in depression (.0001), anxiety (.0001), self-esteem (.0001), hostility (.0001), attention (.0001), hyperactivity (.004) after treatment, but no significant changes were observed for other scales.

Discussion

This study evaluates the characteristics and effects of neurofeedback on adult patients with psychiatric disorders in a naturalistic setting.

In the present study, the most common disease for neurofeedback treatment included depressive disorders. In EEG studies of depression, an abnormal pattern of asymmetric activity in the frontal regions from relative hyperactivity over the right frontal regions and/or relative hypoactivity over the left frontal regions has frequently been observed (Henriques and Davidson 1990). A neurofeedback protocol for modifying this frontal asymmetry has been proposed (Rosenfeld 2000; Rosenfeld et al. 1995). According to the recent paper (Dias and van Deusen 2011), 21 clinical studies reported on neurofeedback treatment in patients with depressive disorders, and there have been only six original articles. These studies were not controlled and included fewer than 15 patients (Baehr et al. 1997, 2001; Earnest 1999; Hammond 2000; Rosenfeld 1997), and all reported positive results (Baehr et al. 1997, 2001; Earnest 1999; Hammond 2000; Rosenfeld 1997). The most

Table 3 Effects of neurofeedback by pre-treatment and post-treatment the Hill–Castro checklist (n = 22)

Variables	Mean ± SD	*t* (*p*)
Attention	54.59 ± 19.04	4.33 (.0001)
	38.68 ± 21.70	
Hyperactivity	47.59 ± 19.36	3.21 (.004)
	34.09 ± 24.06	
Impulsivity	38.27 ± 20.22	3.12 (.005)
	26.55 ± 20.05	
Immaturity	35.64 ± 23.26	3.15 (.005)
	22.86 ± 17.94	
Hostility	37.14 ± 17.99	4.45 (.0001)
	24.55 ± 18.85	
Masochism	9.27 ± 11.19	1.12 (.277)
	7.23 ± 12.81	
Tic	16.41 ± 16.65	2.32 (.030)
	10.82 ± 15.45	
Depression	54.50 ± 20.75	6.11 (.0001)
	31.68 ± 24.68	
Anxiety	51.95 ± 20.46	7.32 (.0001)
	26.86 ± 19.01	
Self-esteem	41.64 ± 20.13	4.28 (.0001)
	28.73 ± 21.79	
Sleep	34.41 ± 23.53	2.39 (.026)
	25.09 ± 24.15	
Others	38.89 ± 13.69	5 (.0001)
	21.21 ± 17.27	

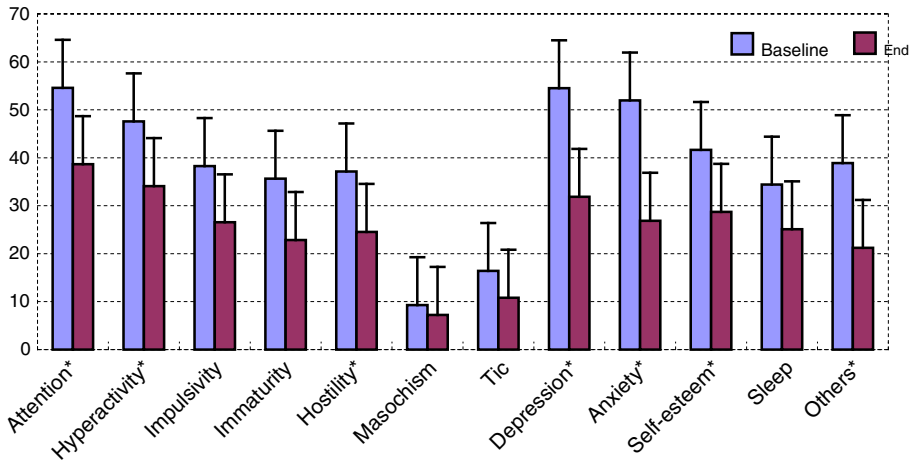

Fig. 1 Effects of neurofeedback by pre-treatment and post-treatment the Hill–Castro checklist. *$p < .005$

commonly used protocol focuses on alpha inter-hemispheric asymmetry and the theta–beta ratio for the left prefrontal cortex (Dias and van Deusen 2011). Choi et al.'s (2011) pilot study is the first randomized controlled trial examining whether alpha asymmetry neurofeedback training can improve symptoms in patients with depressive disorders. Earlier findings suggesting that enhancing the left frontal activity alleviates depressive symptoms were replicated, and cognitive tests showed that asymmetry training improved the performance of executive functions, whereas placebo treatment, no improvement. The Roshi (Hammond 2000) protocol is another protocol for neurofeedback treatment in patients with depression. This protocol is a two-channel unit combining neurofeedback with photic stimulation based mainly on the beta training of the left hemisphere. In the case study, the initial session of EEG neurofeedback using Rosenfeld's protocol was discouraging, and therefore the treatment protocol was shifted to the Roshi protocol for the beta training of the left hemisphere. According to the results, patients became less withdrawn and more active after 30 training sessions (Hammond 2000). In the present study, the treatment protocol for depressed patients was not uniform but individualized. The patient's most serious symptoms were considered for preferential treatment, and the protocol was discussed and adjusted during weekly neurofeedback meetings. For depressed patients, correcting any abnormal pattern of asymmetric activity in the frontal regions and recovering balance in their brain activity played important roles in reducing depressive symptoms regardless of whether the Rosenfeld or Roshi method was employed. Depressed patients with severe anxiety symptoms were treated with SMR at T4 and alpha–theta at Pz. After their serious anxiety symptoms were addressed, treatment goals and protocols were revised to alleviate depression by beta training at F3. On the other hand, depressed patients whose chief complaints were energy loss and concentration difficulties were provided with neurofeedback training starting with beta training at either T3 or F3.

The second most common disease in this study included anxiety disorders. There were studies of neurofeedback treatment in generalized anxiety disorder, phobic disorder, obsessive–compulsive disorder, post-traumatic stress disorder, and panic disorder. Most studies considering anxiety disorders have been case reports with small numbers of subjects, and there is no large, well-controlled study (Moore 2000). Thomas and Sattelberger (1997) treated six chronic anxiety patients with neurofeedback and found an increase in EEG alpha to be beneficial only for patients showing low-amplitude alpha. Those patients with anxiety showing abnormally high levels of alpha at baseline readings did not respond effectively to alpha increase neurofeedback. Their case report attempted to demonstrate the use of EEG feedback to reduce anxiety by reducing alpha activity and increasing beta activity and found that neither should be used as a uniform protocol for treating anxiety disorders but that each case should be planned individually depending on the patient's history and baseline EEG patterns. They suggested that finding some balance in the EEG pattern may be more important than increasing or reducing EEG alpha and called for a controlled study using a larger population for a differential approach to neurofeedback (Thomas and Sattlberger 1997; Plotkin and Rice 1981). In the present study, individualized protocols were determined during neurofeedback meetings for patients with anxiety disorders. According to the patient's chief complaints and baseline readings from the neuropsychiatric evaluation and the subjective-symptom-rating scale, beta at T3 or F3 or SMR at T4 and/or alpha–theta at Pz was selected. For example, a sequential treatment protocol with 10 initial sessions of SMR at T4, followed by 10 sessions of beta training at F3, was applied. Previous studies enrolled volunteers reporting chronic anxiety, but they were not psychiatric patients diagnosed with anxiety disorders according to the DSM. In the present study, only those patients diagnosed with axis I disorders in a clinical setting were recruited.

Other than depression and anxiety, our study also included sleep disorder, somatoform disorder, adjustment disorder, bipolar disorder, ADHD, game addiction and psychosis patients. There were studies that report positive results of neurofeedback treatment on sleep disorder (Arns and Kenemans 2014; Cortoos et al. 2009), substance abuse (Peniston and Kulkosky 1989; Saxby and Peniston 1995; Scott et al. 2005) and ADHD (Moriyama et al. 2012). There were few studies about neurofeedback treatment on psychosis patients or bipolar disorder. Even though the sample size was small, our study results suggested that neurofeedback treatment could alleviate clinical symptoms in patients with variety of psychiatric conditions.

In the present study, neurofeedback could decrease the severity scores of the CGI effectively. The standard CGI is used in virtually all FDA-regulated and most other CNS trials. And it is regarded effective if certain medication or treatment method could decrease severity score of CGI by more than one point (Busner and Targum 2007; Busner et al. 2009).

Neurofeedback treatment improved depression, anxiety, self-esteem, hostility, attention, and hyperactivity based on the Hill–Castro checklist. The exact mechanism underlying its effect on the patients could not be elucidated, but changes not only in mood- and anxiety-related symptoms but also in personality and cognition could be the potential mechanism. Peniston and Kulkosky (1989) found personality changes after alpha-theta neurofeedback treatment in patients with substance dependence but not in the control

group with conventional treatment. Neurofeedback treatment was also considered in the cognitive rehabilitation (Angelakis et al. 2007; Thornton 2000) and could facilitate the function of the left frontal lobe in major depressive disorder (Choi et al. 2011).

The present study has some limitations. First, there was no control group, and the possibility of positive outcomes being due merely to the participants' belief that they were being treated cannot be ruled out. Second, most patients were already receiving pharmacological treatment, and its effects on their symptoms were not controlled for. Third, the patients were not homogenous, and various psychiatric disorders were included. Finally, the treatment protocol was determined according to the patient's subjective symptoms, and the resting-state EEG before treatment was not considered.

Despite these limitations, given the dearth of controlled studies and case reports available, this study contributes by evaluating the use of neurofeedback as a complimentary treatment option for adult psychiatric patients in a naturalistic setting. A controlled study with a larger sample is strongly recommended. The present study's observations are only suggestive of the effectiveness of neurofeedback in addressing symptoms of depression and anxiety in adult psychiatric patients, and there is a need for an individualized protocol for neurofeedback treatment.

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