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Treatment of Depression with Quantitative Electroencephalography (QEEG) of the TQ-7 Neurofeedback System Increases the Level of Attention of Patients

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Abstract

Introduction: As depression is a multifactorial disease, it has been treated using medications, psychotherapy, dietary reeducation and various complementary treatments, including neurofeedback. Of the symptoms, impairment in the level of attention has been a concern for several researchers because of the risk of accidents.

Objective: The aim of this study was to evaluate changes in the level of attention of patients with depression treated by QEEG of the neurofeedback TQ-7 system.

Method: Forty-one patients of both genders were evaluated: 13 male and 28 female patients. The evaluation was divided into three steps. In the first, The Learning Curve (TLC) research protocol of the TQ-7 system was used; in the second stage, the level of attention of patients was evaluated before treatment and in the last stage, it was evaluated after treatment. The Digit symbol, d2, Digit Span in correct and inverse order and the Paced Auditory Serial Addition Test (PASAT) were used to assess attention. The results were analyzed using the paired t-test and expressed as means ± standard error of the mean (SEM) with significance set for p-values ≤0.05.

Results: For both women and men, the scores for focus improved with training by 0.429 and 13.461 (p-value <0.001 for both), sustained attention improved by 39.07 (p-value=0.033) and 69.61 (p-value <0.001), and resistance to interference improved by 0.4 and 2.24 (p-value=0.005 for both), respectively. Short-term memory improved significantly just for the women (0.68; p-value <0.001).

Conclusion: The level of attention increases in patients with depression when treated by QEEG using the neurofeedback TQ-7 system.

Keywords: Depression; Neuro-feedback; Level of attention

Introduction

Depression is characterized by a feeling of deep sadness associated with physiological and cognitive symptoms in the individual [1]. Both the ICD-10 and the American Psychiatric Association in their statistical manual of mental illness (DSM-V) characterize depression as a set of symptoms that include depressed mood (sadness, hopelessness), loss of interest and pleasure for previously satisfactory activities, and decreased energy, leading to a significant lack of enthusiasm that interferes with the life of the individual [2,3].

However, in relation to the etiology, most of the scientific community shares the idea that depression has multifactorial causes [4] that can originate from endogenous (neurobiological, genetic) [5], exogenous (psychosocial) [6] or traumatic factors (shock, letdown or a tumor) [7]. A biochemical alteration in the brain caused by a deficiency of serotonin [8], especially in the synaptic cleft is implicated in the psychogenesis of neurobiological nature, possibly causing an imbalance of both mood and sense of well-being in the individual.

This study focuses on problems of attention due to the possibility of accidents. Even though there are several theories related to the functioning of attention in the literature, Mateer and Mapou proposed a model that integrates all the previously proposed theories [9]. They establish that attention is divided into two cognitive factors: distribution and attention capacity [10].

The deployment/distribution of attention, the ability to channel attention to specific stimuli and sustain the focus on these stimuli, is divided into three aspects. The first is the stage of wakefulness (Arousal), and refers to the level at which the individual is awake, sleepy, torporous or comatose [11]. The second aspect is focused attention, which concerns the individual's ability to select the stimulus of interest from several stimuli. The third aspect is sustained attention,

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Variables	Focused	Sustained Attention	Auditory Attention/Short-Term Memory	Resistance To Interference
	Digit Symbol	d2 Test	Correct Order Digit Span Test	PASAT
Female (Before)	44.46 ± 1.35	377.86 ± 10.07	8.36 ± 0.17	7.21 ± 0.28
Female (After)	44.89 ± 1.37*	416.93 ± 11.8*	9.04 ± 0.10*	7.61 ± 0.24*
	(*p-value <0.001)	**(*p-value=0.033)**	**(*p-value <0.001)**	**(p-value=0.005)**
Male (Before)	47.08 ± 2.42	389.62 ± 13.20	9.54 ± 0.42	6.38 ± 0.42
Male (After)	60.54 ± 0.93*	459.23 ± 9.31*	10.69 ± 0.33	8.62 ± 0.43*
	(*p-value <0.001)	(*p-value <0.001)	(p-value =0.087)	(p-value=0.005)

Subjects with ages ranging from 32 to 67 years were divided into two groups - female patients (n=28) and male patients (n=13). Data are represented as means ± standard deviation (Paired t-test), *p-value <0.05.

Table 1: Assessment of focus (Digit Symbol Test), sustained attention assessment (d2 Test), auditory attention/short-term memory (Digit Span test in correct order) and resistance to interference (Paced Auditory Serial Addition test).

which is determined by the individual's ability to concentrate on the selected stimulus during the time of interest [12].

The union of these abilities demonstrates the dimension of human attention in its full functioning with characteristics that add alertness, focus on attention, maintaining focus, information storage, mental information processing and resisting interference. However, these skills may be impaired if there is interference from intervening variables such as stress.

Although there are studies demonstrating the difficulty of attention due to depression, there are no findings in the literature investigating the treatment of depression and consequently improvement in attention using The Learning Curve (TLC) technique and the neurofeedback TQ-7 system [13]. Thus, the aim of this study was to evaluate changes in the level of attention of patients with depression resulting from treatment using quantitative electroencephalography (QEEG) of the neurofeedback TQ-7 system.

Methods

Subjects

Thirteen male and 28 female patients from the Brain and Neurofeedback Clinic in Recife were evaluated. Subjects were submitted to clinical evaluations under standard room conditions at a temperature of 22° ± 2°C. All the evaluations were performed in a neutral manner, that is, an agreement was reached with each patient so that no symptoms would be revealed before the QEEG examination based on the protocol of The Learning Curve (TLC) Trainer's QEEG (TQ-7) system. The evaluation was divided into three steps. TLC research protocol of the TQ-7 system was used in the first; in the second stage, the level of attention of patients was evaluated before treatment and in the last stage, the level of attention was evaluated after treatment. Patients were informed about the application of attention tests the day before and all subjects agreed to sleep at 8:00 p.m. Each patient was submitted to a total of 40 sessions of neurofeedback of one hour and a half each over twenty weeks. The Digit symbol, d2, Digit Span in correct and inverse order and the Paced Auditory Serial Addition (PASAT) tests were used to assess attention. The inclusion criteria were a clinical diagnosis of depression, signing of written consent forms and age greater than 18. Patients with other medical diagnosis of a psychiatric condition and those unable to follow the treatment process were not included.

TQ-7 System Specifications

The TQ-7 is a system consisting of an amplifier, called Q-wiz, with four simultaneous channels of 24-bit resolution and a maximum sampling rate of 512 samples per second; this means that signals of up to 256 Hz (half the sampling rate) are acquired. Each channel has a 0.2 Hz high-pass filter to eliminate frequencies below this value. Thus, the frequency range of each channel varies between 0.2 Hz and 256 Hz.

The TQ-7 uses the Bioexplorer program for signal analysis. Bioexplorer is a software from CyberEvolution Inc for real time biological signals acquisition, processing, display, recording and playback. It permits the user to mount graphically a setup (also called a "design") for processing raw signals from the Q-wiz amplifier interconnecting various processing, display and audio objects for biofeedback. The processing objects include various types of low-pass, bandpass, high-pass filters, Fast Fourier Transforms (FFTs), mathematical and logical operations. The audio and display objects include display bars with automatic and manual thresholds, graphical trends, power spectrum, audio and MIDI playback, video player and flash game players, all of them controlled by processing objects.

A standard was established for TLC investigation protocol of the TQ-7 system [13,14] in relation to the expected conformation of depression symptoms. In TLC protocol for the TQ-7 system, it is possible to identify a pattern of brain electrical activity that signals the presence of symptoms of depression named by Van Deusen as Reversal [13].

It was demonstrated that within this category it is possible to find specific symptoms for two types of depression: depression with symptoms of hopelessness and symptoms of agitated depression [13].

The symptoms of depression with hopelessness are: sadness, loss or significant decline of interest in performing activities previously considered pleasurable, social withdrawal, altered appetite, changes in sleep quality, slowing of speech and in some cases mutism, fatigue, guilty feelings, cognitive disorders and thoughts related to death. These symptoms are associated to a reversal or asymmetry of alpha waves (8-12 Hz) [13,15,16]. Thus, it was observed the importance of the right hemisphere represented by eight even points (Fp2, F4, F8, C4, T4, P4, T6 and O2) [13,17] of the international 10-20 electroencephalography mapping system. These points contained around 10 to 15% more alpha waves when compared to the left hemisphere represented by eight odd points (Fp1, F3, F7, C3, T3, P3, T5 and O1) as the alpha waves emit less energy [18] compared to beta waves. This same ideal alpha pattern is expected in the posterior region of the brain at five points (T5, P3, Pz, P4 and T6), when compared to the anterior region also at five points (F7, F3, Fz, F4 and F8), totaling 26 points, divided in two groups of 13 [13].

The symptoms of agitated depression are irritation, impatience, overemotional and difficulty concentrating and paying attention and subjects have a struggle to create a routine and maintain it. These symptoms are linked to reversals of beta waves (15-23 Hz) 13, which are expected to be around 5% higher in the left hemisphere (Fp1, F3, F7, C3, T3, P3, T5 and O1) and in the anterior brain (F7, F3, Fz, F4 and F8) compared to the right hemisphere (Fp2, F4, F8, C4, T4, P4, T6 and O2) and posterior portion of the brain (T5, P3, Pz, P4 and T6), respectively [13]. The attention theory of Mateer and Mapou [9,10,19,20] is guiding this study.

The Deployment/distribution of attention can be evaluated in tasks of fast exploration of target identification with the Digit Symbol, Trail Making Tests, d2 and others. The Digit Symbol and d2 tests were used in this experiment to evaluate the focus and maintaining the focus, respectively [20]. The Digit Symbol test requires the subject to pair symbols with their respective numbers from 1 to 9 within 1 minute and 30 seconds. Whereas in the d2 test, the individual should cross out the letter d when it has two lines above or below it or single lines above and below it on a specific form of 14 lines with 47 letters on each including distractors [9].

Attention capacity/encoding refers to the situation where the individual can capture and store data in order to process them mentally while resisting external interference [11]. The Correct Order Digit test starts with a 2-digit sequence that increases progressively. The subject is asked to repeat this sequence correctly. This is an indirect way of measuring the amount of information that the subject is able to retain. The Reverse Order Digit test is similar to the Correct Order Digit test but the subject must repeat the sequence of digits in reverse order. For example, if the sequence is 1-9-3, the individual should say 3-9-1, and so on [20]. In this test, in addition to retaining information in the memory, the subject must also mentally manipulate this information; the subject remembers the sequence, reverses the order, and says the new order out loud. The Paced Auditory Serial Addition test (PASAT) is a test that evaluates the mental capacity of the subject to process information as well as to resist divided attention 9. This resistance to external interference is the third sector that must be evaluated to verify attention capacity. In this test, the subject must sum dictated numbers. The examiner says two numbers, and the subject must add up them up and say the answer, for example, 9, 8=17. When the examiner says the next number, the subject must add it on to the last number of the previous pair, that is, eight and not its total seventeen. The subject must remember the last number spoken and discard the total which was the sum of the previous two numbers. This test demands that the subject is able to mentally process information and, at the same time, resist interference [9,19].

Groups

As a longitudinal cross-sectional study (before and after) was performed in subjects with ages ranging from 32 to 67 years old, divided into two groups: female patients (n=28) and male patients (n=13).

Data analysis

The results of the individually applied attention tests were analyzed using the paired t-test, expressed as mean ± standard error mean (SEM) and presented in Table 1. Significance was set for p-values ≤0.05.

Results

Assessment of the level of attention

Attention focus evaluation - Digit symbol test: Female (before: 44.46 ± 1.35; after: 44.89 ± 1.37) and male subjects (before: 47.08 ± 2.42; after: 60.54 ± 0.93) presented greater attention focus after training with neurofeedback compared to their focus of attention before training with neurofeedback (p-value <0.001) (Table 1).

Sustained attention - d2 test: Female (before: 377.86 ± 10.07; after: 416.93 ± 11.8) and male subjects (before: 389.62 ± 13.20; after: 459.23 ± 9.31) presented greater sustained attention after neurofeedback training compared to before training with neurofeedback (p-value=0.033 and p-value <0.001, respectively) (Table 1).

Auditory attention or Short-term memory - Correct Order Digit Span Test Only female subjects (before: 8.36 ± 0.17; after: 9.04 ± 0.10) presented better short-term memory after training compared to before training with neurofeedback (p-value <0.001) (Table 1).

Mental manipulation - (Reverse order digit span test): Female (before: 4.57 ± 0.15; after: 4.68 ± 0.14) and male subjects (before: 5.92 ± 0.31; after: 7.54 ± 0.62) presented higher results in the reverse order Digit Span test after training with neurofeedback compared to the results prior to training (p-value=0.083 and p-value=0.082, respectively). However, no statistically significant improvements were found with neurofeedback training.

Resistance to interference - Paced auditory serial addition test (PASAT): Female (before: 7.21 ± 0.28; after: 7.61 ± 0.24) and male subjects (before: 6.38 ± 0.42; after: 8.62 ± 0.43) showed greater resistance to interference after training with neurofeedback compared to prior to training (p-value=0.005) (Table 1).

Discussion

This study found increased attention with better sustained attention, auditory attention/short-term memory and resistance to interference in patients of both genders with hopeless depression and agitated depression trained using the TQ-7 system of TLC neuro-feedback technique [13].

Although the mental manipulation capacity presented higher values in the reverse order Digit Span test for both genders, no statistically significant difference was found. Perhaps, this result is related to the low number of subjects enrolled in this study as the result is very close to the significance level of p-value <0.05.

Based on the results found in the attentional tests, there was also a congruence in the patients' reports regarding the reduction of DSM-V symptoms associated with depression and reversal or asymmetry of alpha and beta waves using the neurofeedback TQ-7 system of TLC technique [13,14].

This study corroborates the findings of Simkin et al. [21] on the question of treating depression even though the methodological processes used were different. Simkin et al. used neurofeedback with low-resolution tomography (LORETA) 32 due to physiological restrictions linked to possible patterns captured by the human electroencephalogram interconnected to the standard statistical chart of the normal curve called the z-score [22] recently validated by Thatcher et al. [23]. However, in this study we used the standard TQ-7 system TLC protocol specific for depression, that is, asymmetry [18,24] or reversal category [13].

Regardless of the neurofeedback system used, several studies in the area of neurophysiology [13,21,23,25] have already shown that brains are organized by means of rhythmic oscillations expressed in different frequencies produced by constant firing of the neurons. The constant changes in the patterns of these brain waves seem to be directly related to mental states and these changes are only possible due to neuronal neuroplasticity, which can be accessed through the electroencephalogram [26].

Conclusion

With quantitative electroencephalogram (QEEG) it is possible to observe several patterns that include optimal states of psychic balance, but also states of fear, anxiety, panic, anger, impatience and depression. According to Fisher (2014), these states arise from developmental

trauma disorders [26,27], above all, from affective regulation problems. These patients live in the absence of the mother [26]. The infant's early developing right hemisphere has deep connections into the limbic and autonomic nervous systems and is dominant for the human stress response, and in this manner the attachment relationship facilitates the expansion of the child's coping capacities [28].

Thus, these patients find it difficult to develop the sense of self, and brain training with neurofeedback may help build new circuits that minimize fear, shame, and anger [26], that is, compromised brain development can affect emotional control, Control of verbal or behavioral impulses and neurocognition as intelligence, memory, perception and attention.

In this sense, this study demonstrated that, among the neurocognitive impairments caused in a brain with depression, the attention, indeed, was affected. However, after 40 sessions of brain training with neurofeedback, it was possible to reestablish a high level of distribution and attention capacity of these patients.

Although all patients were asked to sleep at 8:00 the day before the attention tests were applied, it is difficult to verify whether this really happened. As data on this subject are scarce in the literature, it is still difficult to compare these results with other researchers. It is therefore important that further research is carried out with larger cohorts to confirm the results found in this study.

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