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Research Article

Home Based Neurofeedback and GFCF Diet for İmproving Developmental Brain Conditions

Gelişimsel beyin durumlarını iyileştirmek için evde nörogeribildirim ve GFCF diyeti

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Abstract: Neurofeedback is a kind of neurofeedback which is used for improving many brain conditions, but it requires to be applied in order to overcome specific symptoms at least three times a week, around 100 times in total**.** The research put forward that in individuals with ASD, gluten-free/casein-free and ketogenic diets can play a role in alleviating ASD symptoms. Specific diets together with neurofeedback may improve autoimmune conditions, brain health and development. Neurofeedback by improving self-control of brain functions may alter the Glutamate and GABA metabolism in a positive way. By changing the brain condition using neurofeedback, we may change the function of whole metabolism. Specific diets in return help to solve the underlying metabolism problem and make the effects of neurofeedback long-lasting. In this review article, we have investigated methods and applications which enables to use neurofeedback at home safely under the surveillance of medical doctors.

Keywords: EEG, neurofeedback, GFCF diet(Gluten free/casein free diet), ADHD, learning disability, autism

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Özet: Nörogeribildirim, pek çok beyin durumunu iyileştirmek için kullanılan bir biogeribildirim yöntemidir. Ancak etkin sonuç almak ve bazı özel durumların üstesinden gelebilmek için haftada en az 3 kez, toplamda 100 kez civarında uygulanmalıdır. Araştırmalar, Otizmde gluten ve kazein içermeyen ve ketojenik diyetlerin Otizm semptomlarını azalttığını göstermektedir. Nörogeribildirim ve özel diyetler otoimmun durumlarda beynin sağlığını ve gelişimini olumlu etkileyebilir. Nörogeribildirim, beyin fonksiyonlarının kendi kendine kontrolünü artırarak Glutamate ve GABA metabolizmasını olumlu etkilemektedir. Nörogeribildirim ile beyin durumunu değiştirdiğimizde, tüm metabolizmanın daha etkin çalışmasına yardımcı olabiliriz. Diyetler, altta yatan metabolizma probleminin düzelmesine olumlu etki sağlayabilir ve nörogeribildirimin etkisini uzun ömürlü yapabilir. Bu makalede, nörogeribildirimin evde doktorların gözetiminde güvenli bir şekilde uygulanmasına yardımcı olan metod ve uygulamalar incelenmiştir.

Anahtar Kelimeler: EEG, nörogeribildirim, GFCF diet, DEHB, öğrenme güçlüğü, otizm

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1. Introduction

Neurofeedback is a kind of biofeedback where the brain signals of a subject are fed back to himself for teaching the self-regulation and self-control of brain signals. Neurofeedback usually provides visual and auditory feedback. Undesirable brain activities are suppressed with negative feedback, and the desired brain activities are empowered with positive feedback. Neurofeedback is applied for 20-40 minutes 3 times a week, more than 100 times. Upon continuous usage for more than 20 sessions, the change in behavior can be monitored in the subject's life[1].

The electroencephalography (EEG) is recorded during the neurofeedback treatment. Then, its various components are extracted and fed to subjects using online feedback loop in the form of audio, video or their combination. During this procedure, the subject becomes aware of the changes occurring during training and will be able to assess his/her progress in order to achieve optimum performance. For instance, the subject tries to improve the brain patterns based on the changes that occur in the audio visual cue. The most commonly used protocols are reducing slow brain waves (Delta and/or Theta and Theta/Beta1) while eyes are open, improving low beta while eyes are open, rewarding theta over alpha while eyes are closed (Alpha/Theta neurofeedback), improving SMR[1].

Neurofeedback is used for improving many brain conditions, namely ADHD, epilepsy, schizophrenia, learning disabilities, autism, and migraines[1]. In this review, we will focus on neurofeedback applications for developmental brain conditions (ADHD, learning disabilities, autism) where the basis of the brain conditions is linked with autoimmune system disorders.

Developmental brain conditions which are linked with autoimmune disorders

A core characteristic of autoimmune problems is an imbalanced, less rich and/or diverse gut microbiota early in life, influenced by priming, factors affecting microbiota development and function (e.g. early microbial exposure, diet, stress, vitamin D status) as well as epigenetic regulation of gene expressions. A continuously varying genetic vulnerability can be expected[2].

If viewing dysfunctional behavioral accommodation to current environmental demands as a mismatch between early calibration of physiological systems and the actual context faced, i.e. maladaptive homeostasis and/ or discoordination between homeostatic systems, the question arises to what extent this regulatory imbalance can be adjusted by later interventions. Preclinical research has shown promising results that targeting the microbiota, particularly during critical microbial-neural developmental windows, hold a potential of preventing later neurodevelopmental deficits, hypothetically by affecting homeostatic calibration of HPA-axis, metabolic, cardiovascular, gastrointestinal and immune system function and/ or the coordination between these systems[2].

The microbiome-gut-brain axis paradigm implies that ADHD, learning disabilities and autism, central nervous system and behavioral symptoms may be secondary to enteric nervous system dysfunction or dysregulation. If so, metabolic and immunologic function should be evaluated in diagnosis and targeted in treatment as well as prevention. If the gut microbiome is imbalanced, alterations in metabolic activity such as nutrient absorption and waste disposal can be expected. The implicit hypothesis that suboptimal nutrition possibly caused by inborn metabolic dysfunction may underlie symptomatology has been addressed in a review of broad-spectrum micronutrient approaches as treatment for symptoms[2][18].

The research put forward that in individuals with ASD, while gluten-free/casein-free and ketogenic diets, camel milk, curcumin, probiotics, and fermentable foods can play a role in alleviating ASD symptoms, consumption of sugar, additives, pesticides, genetically modified organisms, inorganic processed foods, and hard-to-digest starches may aggravate symptoms[22][20]. Specific diets together with neurofeedback may improve autoimmune conditions, brain health and development[19][20]. Neurofeedback by improving self-control of brain functions may alter the Glutamate and GABA metabolism in a positive way. By changing the brain condition using neurofeedback, we may change the function of whole metabolism. Specific diets in return help to solve the underlying metabolism problem and make the effects of neurofeedback

long-lasting. So neurofeedback and specific diets have complementary effects[21].

Neurofeedback Methodology

Converting Time Series domain EEG data to frequency domain EEG data:
Activities of cerebral neurons have rich information about neuronal activities. When neurons are activated, they produce electrical pulses. By placing electrodes on the scalp, the electrical activity of the brain, known as EEG, can be recorded. In turn, EEG is generated by a specific type of synchronous activity of neurons which are known as pyramidal neurons and the electrical output is thus reflected in the following areas of the skin where the electrodes are located. Different patterns of electrical activity, known as brain waves, could be recognized by their amplitudes and frequencies. Frequency indicates how fast the waves oscillate which is measured by the number of waves per second (Hz), while amplitude represents the power of these waves measured by microvolt (μV)[1].
The so-called quantitative EEG (QEEG) signal evaluation method, i. e. the frequency analysis of EEG signals with the application of computer processing, could be simply accomplished. With the use of Fourier transform, the digital EEG signals using QEEG are converted so that frequency bands and brain wave intensity can be defined and visualised in an exact way according to their frequency spectra[1].
Different frequency components are categorized into delta (less than 4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (30-100 Hz) where each represents a particular physiological function. These frequency components have subsets. For example, sensorimotor rhythm (SMR) frequency bands (13-15 Hz) are related to the sensorimotor rhythm and entitled as low beta[1].

EEG Electrode Placement

Electrodes can record those cortical activities of the brain regions that are close to them. Electrode System 10-20 and 10-10 are methods for standardizing areas of the skull and comparing data. The term "10-20" refers to the placement of electrodes over 10% or 20% of the total distance between specified skull locations. Studies have shown that these placements correlate with the corresponding cerebral cortical regions. Of 21 electrodes, 19 are used for recording cortical areas and 2 other electrodes as reference electrodes. The skull regions are named using letters and numbers. Letters correspond with the brain regions and numbers to the hemisphere of the brain or the locations of this hemisphere. The letters F, P, T, O, and C are related to frontal, parietal, temporal, occipital, and central areas, respectively. Odd/even numbers are associated with the left/right side of the brain region[1].
The most frequently used neurofeedback is frequency/ power neurofeedback. This technique typically includes the use of 2 to 4 surface electrodes, sometimes called "surface neurofeedback". It is used to change the amplitude or speed of specific brain waves in particular brain locations[1].

Clınıcal Applıcatıons

1. Attention Deficit/Hyperactivity

Studies showed that people with ADHD disorder have slower brain wave activity (theta) and less beta activity compared to normal people in their frontal lobes. ADHD originates and develops from disturbance of microbial metabolism early in life and subsequent disturbance of among other tryptophan, serotonin, dopamine, norepinephrine, Glutamate and GABA metabolism or formation[2].
In ADHD, the goal is to decrease the brain activity in the theta band and to increase its activity in the beta band (or to decrease theta/beta ratio) at the frontal lobes [3] or increase SMR at central electrodes (Cz). This treatment is effective in reducing hyperactivity; Increasing focus, grades, and parental consent from children's behavior; and improving indicators of sustained attention [4].

2. Learning disabilities (dyslexia, disgraphia, dyscalculia, dispraxia)

Although IQ is measured as normal or above normal, some people face difficulty in reading, writing, learning mathematics and/or learning other tasks in general. This situation is called specific learning disability. If the difficulty is in reading, it is called as dyslexia; if the difficulty is in writing, it is called as dysgraphia if the difficulty is in learning mathematics, it is called as dyscalculia, and if the difficulty is in physical coordination of tasks, it is called as dyspraxia. One or more learning difficulties may exist at the same time, it is also comorbid with ADHD.

These disorders are more common at school age and patients with dyslexia have trouble in reading and spelling the characters [5]. More than one brain regions get affected and there are disconnection between brain lobes and there are coherence anomalies. Normalizing coherence in frequency bands between brain regions are the main aim of neurofeedback studies[6]. Also, reducing theta at Broca Area, electrode FC5 in 10-10 electrode system, improves speech[7]. Improving SMR also helps reducing inattention[7]. Theta/Beta-1 inhibition protocol is also used for learning disabilities[8].

3. Autistic spectrum disorder

(ASD) is a neurodevelopmental disorder with challenges that maintain in adulthood. Children with autism have difficulty in functions such as social interaction, verbal and nonverbal communication, behavior and interests. ASD may be associated with emotional problems, mental retardation, or seizure disorders. These children may also have extreme sensitivity to sounds and smells. Also, children with autism may show idiosyncratic behaviors, obsessive rumination, poor social interrelatedness, and flat affect. Researchers found out that individuals with autism differ from normative samples with regard to impediments in empathy or theory of mind (TOM) tasks, weak central coherence, and executive functioning[1]. There are several diagnostic tools designed to show abnormalities in brain's function for autism. They are (1) High-beta activity related to anxiety; (2) The high activity of delta/theta corresponding with the slow cortex, lack of attention, impulsivity and hyperactivity; and (3) Abnormal EEG/seizure activity (4) Abnormal Gamma activity, either too low or too high frequency amplitudes[16][17]. High beta type is the most common one seen among children with ASD (approximately 50- 60% of individuals with ASD)[9]. The goal of neurofeedback in children with autism is to inhibit theta, and to enhance beta-1 wave. Also mu power suppression (between 7.5Hz- 12.5 Hz) at C3 and C4 electrode places which is known as human mirror neuron system is applied as neurofeedback protocol[10].

Home Based Neurofeedback

Currently, neurofeedback solutions are applied at psychiatrist's office 20 – 150 times depending on the severity of the condition. The solutions are expensive and require expertise.
Taking a child to psychiatrist 3 times a week is difficult. With new technological advancements, it is now possible to develop neurofeedback applications which may be used at home for personal needs. In that way, doctors may follow up many cases in parallel and the subjects improve their brain conditions with cost conscious solutions.

There are home based solutions in the market

Neurosky-Mindflex

MindFlex is a brain trainer device based on the ThinkGear technology that was developed by NeuroSky. The device contains a controlled unit and a wireless EEG headset. This MindFlex EEG headset can be fixed on the head thanks to its rubber design. Brain signals are detected by a metal electrode constricted to the forehead by monopolar method and the null point is the electrode clipped on the earlobes (null reference). The signal processing unit, also developed by the ThinkGear technology of NeuroSky, can determine the value of concentration or attention. Neurosky has one electrode placed at forehead, and can be used to improve attention for ADHD. It does not contain norm brain mapping data [11].

Mente Autism

A novel NFB in the treatment of ASD using the Mente Autism (AAT Medical, Malta) active portable NFB device composed of a headset, software and a cloud component. [12].
The Mente device is designed to utilize the EEG activity of children diagnosed with ASD to provide a home-based support therapy in order to promote relaxation as well as engagement of the subject. The device reads the EEG, augmented in a real-time NFB training in association with auditory therapy that is delivered through binaural beat sounds transmitted via earphones connected directly to the headband. The headband houses 4-EEG channels and a bias electrode system. The EEG signal is bipolar between the 2 EEG Sensors placed on the front of the head (Fp1 and Fp2), taken as active, and each of the 2 sensors placed at the back of the head (O1 and O2), taken as reference. The fifth sensor (FPz, placed between Fp1 and Fp2) is used as bias to minimize the DC and common-mode AC signals. This system can

be used as a stand-alone system, with all collected raw EEG data being stored and processed on the device, thus allowing for the user to move around freely without any hindrance from added devices[12].

All the analyses are performed on the Mente device with the raw data from each channel (Fp1-O1, Fp1-O2, Fp2-O1, Fp2-O2) passed through two 121th order FIR filters (High pass: Fstop1 = 0.25 Hz, Fpass1 = 1.25 Hz; Low pass: Fpass2 = 40 Hz, Fstop2 = 42 Hz), then an automated Eye Blink correction (12) is applied to remove eye blink artifacts. Then the signal is averaged between all the channels with a Fast Fourier Transformation (FFT). The following bands are selected from the FFT: Delta (1–3 Hz), Theta (4–7 Hz), Alpha (8–13 Hz), Beta1 (14–19 Hz), Beta2 (20–35 Hz). The results are updated every second and an auditory feedback is delivered in the form of binaural auditory beats. The binaural beats produce a perceptual phenomenon that occurs when two tones of a slightly different frequency are presented separately to the left and right ears resulting in the listener perceiving a single tone that varies in amplitude at a frequency equal to the frequency difference between the two tones. The binaural beats delivered by Mente Autism are in the range of delta, theta and beta frequency and are selected accordingly to the user's predominant frequency. The NFB protocol delivered by the device aims to reduce the abnormal EEG pattern associated with ASD that is characterized by excessive power at low-frequency (delta and theta) and high-frequency (beta) bands, as well as reduced power in the middle-range frequency band (alpha). At the end of a treatment session, the data collected are sent to a secure cloud system where they are stored. [12].

Auto Train Brain

Auto Train Brain is a neurofeedback and multisensory based mobile phone software application, designed in Sabancı University laboratory with the aim of improving the cognitive functions of dyslexic children. It reads electroencephalography (EEG) signals from 14 channels of eMotiv EPOC+ and processes these signals to provide neurofeedback to child for improving the brain signals with visual and auditory cues in real time[13][14][15].

There are six neurofeedback protocols implemented in Auto Train Brain: Reducing Theta waves at left hemisphere and right hemisphere, and reducing Theta/Beta1 ratio at Broca area, Wernicke area, frontal lobes, right parietal lobe, improving low Beta at frontocentral electrodes. These protocols are relevant for ADHD, learning disabilities and autism. In the near future, other protocols (alpha/theta neurofeedback, Mu suppression protocol) will also be included.

2. Conclusıon

In Neurofeedback, EEG is usually recorded, and various brain-activity components are extracted and feedback *-to subjects. During this procedure, subjects become aware of the changes that occur during training and are able to assess their progress in order to achieve optimal performance. Electrode placement is performed according to specific brain functions and specific symptoms. Home based neurofeedback equipment and software are newly emerging technological innovations. In this article, we have reviewed home based therapies for developmental brain condition (ADHD, autism, learning disabilities) and emphasized the impact of neurofeedback when used with specific diets to improve the auto immunity to reduce the overall symptoms.

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