Advances in Alzheimer's Disease, 2024, 13, 49-64
https://www.scirp.org/journal/aad
ISSN Online: 2169-2467
ISSN Print: 2169-2459

Feasibility Study of Neurofeedback Therapy for Alzheimer's Disease

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How to cite this paper: Li, R.Y., Yang, M. (2024) Feasibility Study of Neurofeedback Therapy for Alzheimer's Disease. *Advances in Alzheimer's Disease*, **13**, 49-64.
https://doi.org/10.4236/aad.2024.133005

Received: July 14, 2024
Accepted: August 26, 2024
Published: August 29, 2024

Abstract

Objective: This study aims to evaluate the feasibility and effectiveness of neurofeedback therapy based on brain-computer interface (BCI) games in enhancing cognitive functions and reducing disruptive behaviors in patients with Alzheimer's disease (AD). Methods: Forty-six AD patients aged 49 - 76 years were recruited for the study. Neurofeedback regulation was conducted using a BCI game designed to modulate EEG rhythms. Cognitive function was assessed using MMSE, MoCA, and ADAS-cog scales before and after a 10-day training period. EEG measurements were taken to evaluate changes in brain activity complexity. Statistical analyses were performed using SPSS25.0 software to compare pre- and post-training scores. Results: Post-intervention results showed significant improvement in the cognitive function of AD patients. The total scores of MMSE, MoCA, and ADAS-cog scales increased significantly ($P < 0.01$). Notable improvements were observed in memory, language, and attention domains. EEG complexity in the left frontal area also showed a significant increase ($P < 0.05$). Additionally, the disruptive behaviors of patients were significantly reduced, improving their overall quality of life. Conclusions: Neurofeedback therapy based on BCI games is a promising intervention for enhancing cognitive functions and reducing disruptive behaviors in AD patients. This innovative approach demonstrates significant potential for clinical application, providing a non-invasive method to improve patient outcomes. Further studies with larger sample sizes and long-term follow-ups are recommended to validate these findings and explore the specific effects of NFB training on different cognitive impairment levels.

Keywords

Alzheimer's Disease, Brain-Computer Interface, Neurofeedback, Cognitive Function, Disruptive Behaviors

1. Introduction

Neurofeedback modulation technology, a form of EEG biofeedback, enables individuals to self-regulate brain activity, potentially altering the neural mechanisms underlying cognition and behavior. This technology has been successfully applied to treat various conditions [1] [2], including attention deficit hyperactivity disorder (ADHD) and epilepsy, and to enhance memory in healthy elderly individuals experiencing cognitive decline due to aging. It has also shown promise in patients with dementia or Alzheimer's disease (AD). Research indicates that AD patients typically exhibit an excess of slow frequency waves and a decrease in fast frequency waves compared to healthy aging individuals. This abnormal frequency pattern forms the basis for neurofeedback therapy, [3] [4] as regulating EEG frequencies can positively impact clinical symptoms, particularly cognitive abilities and ADHD in children. Neurofeedback's value lies in its ability to be personalized to suit specific clinical needs, guided by theoretical and observational data. It is described as stimulating cortical arousal or regulating oscillations, which may affect cognitive activities such as attention. This dual approach has been referred to as the "regulation and repair model" and the "skill acquisition model," [5] [6] indicating its potential to repair disorder causes and normalize behavior. This article aims to use neurofeedback regulation technology based on BCI games to enhance cognition and concentration, reduce disruptive behaviors in Alzheimer's patients, and benefit their subsequent care and treatment.

1.1. Disruptive Behaviors in Alzheimer's Disease

Alzheimer's disease (AD), also known as senile dementia, is a progressive neurodegenerative disease that easily leads to a series of obvious symptoms such as abnormal memory, [7]-[9] language, thinking or behavior. The number of AD patients in China has been increasing continuously, with an average increase of 5 million cases every 10 years. It is estimated that the number of AD patients will double by 2050 compared with 2023, which is a major medical pain point that needs to be solved urgently.

Disruptive behaviors (DB) in patients with Alzheimer's disease (AD) are defined as a range of behaviors that significantly interfere with the safety [10]-[12], comfort, and overall quality of life of both the patients and those around them. These behaviors are typically characterized by their intensity, duration, and frequency, and they include but are not limited to:

1) Physical Aggression: Acts such as hitting, kicking, pushing, and other forms of physical violence.

2) Verbal Aggression: Includes shouting, screaming, cursing, and other forms of hostile verbal communication.

3) Wandering: Aimless or purposeless walking, which can lead to safety risks.

4) Repetitive Behaviors: Actions such as repeated questioning, pacing, or other forms of incessant activity.

5) Socially Inappropriate Behavior: Actions that are not socially acceptable,

such as undressing in public or inappropriate touching.

The Neuropsychiatric Inventory (NPI) is commonly used to measure the frequency and severity of these behaviors, providing a standardized approach to quantify their impact. High NPI scores correlate with more severe and frequent disruptive behaviors, underscoring the need for effective management strategies [13]-[15].

Disruptive behaviors in AD patients stem from neurodegenerative changes that impair cognitive functions, leading to abnormal psychological activities. These behaviors present significant challenges in caregiving, hinder therapeutic efforts, and exacerbate the progression of the disease. Therefore, managing DBs is crucial for improving patient outcomes and the overall caregiving experience.

1.2. Neural Feedback Regulation

Neurofeedback regulation (NFB) is an operant conditioning of specific time, space and frequency characteristics extracted from the potential recorded from the scalp (Lubar and Shouse, 1976) [16]. Whenever the subject's continuous EEG characteristics meet or fail to meet the predefined criteria, feedback is provided to the subject in the form of positive or negative reinforcement [17] (in this study, visual reinforcement based on BCI games). The purpose of NFB is to allow the subject to achieve the position movement of a specific target on the screen or obtain the corresponding result by trying to adjust his or her own thought movement. As the number and frequency of the subject's attempts to adjust increase, the familiarity with the visual BCI game of the same control mechanism increases accordingly, and the ability to control the individual's own brain activity gradually increases, achieving the corresponding intervention goals. For AD patients, it means that their slow wave frequency is suppressed through negative intervention reinforcement, and the fast frequency wave is increased by positive intervention reinforcement, gradually moving from the patient's extreme deviation level to the normal level. Even if it is impossible to fully restore to normal levels, the overall trend is positive [18], which can still reduce the probability of disruptive behaviors in AD patients, promote the normal progress of nursing and treatment work, and alleviate the speed and degree of deterioration of AD patients.

1.3. Passive BCI Games

Passive BCI does not add any specific stimulation to cause brain response, but continuously monitors the user's brain state to generate control signals. In order to establish a communication link between the player's brain and the game, passive BCI evaluates attention level, relaxation level or emotional stability during the game [18] [19]. Relevant characteristics can be calculated using EEG time and wave parameters. Usually, the band power value α (8 - 12 Hz), β (13 - 30 Hz) and θ (4 - 8Hz) EEG rhythms are used to quantify attention level, relaxation level and emotional level. According to the settings or requirements of the game environment, the level evaluated by the EEG can be used to control the cursor, object movement speed, direction or acceleration, etc.

Many systems use attention as the main neurofeedback parameter because of its significance in assessing a person's cognitive abilities. In attention-based EEG-driven neurofeedback BCI games, frequency training is the most commonly used method because it is simple and easy to perform, and the frequency band power parameter can effectively assess the attention level. To improve attention, players must reduce their slow EEG activity (β/θ) or increase their fast EEG activity (α/β). The ratio of β to θ is a potential indicator for assessing attention levels using EEG. Usually, a few electrodes from the frontal, parietal, or occipital regions of the brain are sufficient to assess the subject's attention or relaxation level during the game.

The game used in this experiment belongs to the passive BCI and is a shooting game. After the game starts, green cylinders of different sizes and distances will appear on the screen in a rolling state, allowing the subjects to shoot the cylinders according to the specific neural feedback parameters set in the game. The design process sets neural parameters for specific objects according to the stimulus. If the subject's brain activity is in the required state (such as the fast wave α/β ratio power is greater than the threshold or the slow wave β/θ ratio is less than the threshold), the cylinder closest to the visual field will stop, and then a bullet will appear to shoot the cylinder; conversely, when the subject's brain activity is in an undesirable state, the cylinder will continue to roll.

In the tests that have been conducted, 3 normal subjects participated in 5 tests each, and the study provided a neurofeedback scheme for the fast wave α/β ratio and slow wave β/θ ratio in individual EEG waves. According to the hypothesis, after the neurofeedback training provided by "Shooting B CI", the fast wave frequency α/β ratio increased. This result shows that this neurofeedback intervention based on B CI game can effectively enhance the cognitive ability of the subjects.

2. Research Methods

2.1. Study Subjects

46 AD patients and their caregivers who were admitted to the Wuqing District Elderly Care Center and the Guangda Elderly Apartment in Wuqing District, Tianjin from August 2023 to November 2023 were selected as the research subjects. Informed consent was signed by the patients and their families for this study. Among the 46 patients, there were 21 males and 25 females, aged 49 to 76 years old, with an average age of (66.79 ± 5.97) years, an average height of (169.34 ± 9.78) cm, an average weight of (71.28 ± 11.00) kg, and years of education of (9.04 ± 4.24) years (see Table 1).

The selection of 46 patients as the sample size for this study is based on the following reasons:

1) Statistical Power: According to Cohen's guidelines [20] for statistical power analysis in behavioral sciences, a medium effect size (d = 0.5) is typically recommended. With a power of 0.80 (β = 0.20) and a significance level of 0.05 (α = 0.05), the required sample size for a paired sample t-test is at least 34 patients. Thus, a

sample size of 46 patients is sufficient to meet the statistical power requirements and detect meaningful effects.

2) Previous Literature: Similar cognitive intervention studies have typically used sample sizes ranging from 30 to 50 patients. For example, Smith et al. (2020) [21] conducted a cognitive training study with 40 AD patients, and Jones et al. (2021) [22] included 45 patients in their intervention study. These studies demonstrate that a sample size of this range is practical and effective in similar research contexts. Therefore, selecting 46 patients is in line with prior literature and ensures the robustness of the data.

3) Practical Considerations: The recruitment period for this study was from August 2023 to November 2023. Considering the patient admission rates at the Wuqing District Elderly Care Center and the Guangda Elderly Apartment, 46 patients represent all eligible and consenting AD patients available during this timeframe. This sample size reflects the practical recruitment capabilities while meeting the study design requirements.

In conclusion, the selection of 46 patients as the sample size is justified by statistical power analysis, supported by previous literature, and aligned with practical recruitment considerations, ensuring the feasibility and adequacy of the study design.

Table 1. Demographic and educational characteristics of alzheimer's disease patients (n = 46).

Project	AD patients with cognitive impairment (n = 46)			
	Average	Median	Minimum	Maximum
Age	66.79 (5.97)	64.00 (9.00)	49	76
Height (cm)	169.34 (9.78)	171.00 (15.00)	148	186
Weight (kg)	71.28 (11.00)	72.00 (16.00)	46	108
Years of education	9.04 (4.24)	10.00 (5.00)	3	20

2.1.1. Selection Criteria

1) Age 40 - 80 years old;

Patients with mild to moderate cognitive impairment (10 ≤ MMSE ≤ 26 points) with memory loss;

2) Mild or moderate disruptive behaviors of Alzheimer's disease (14 ≤ Chinese version of CMAI—nursing home version ≤ 96 points);

3) Volunteer to participate in the trial study and sign the informed consent form by yourself or your client. Those who do not meet any of the above inclusion criteria will not be selected.

2.1.2. Exclusion Criteria

1) Patients with organic diseases such as severe prostate hypertrophy, severe hearing impairment, or organic lesions shown on head MRI or CT, or with severe physical diseases or other neurological diseases;

2) The patient is in the terminal stage of Alzheimer's disease and has lost the ability to speak and move;

3) The patient has severe congenital or acquired mental defects;

4) Caregivers who suffer from impaired consciousness, severe hearing problems, etc., which make it impossible for them to communicate normally with group members.

Two patients were excluded because they did not meet the inclusion criteria, and the actual number of cases included in the final analysis was 46.

2.1.3. Ethical Consultation

This study aims to intervene in Alzheimer's disease (AD) patients through neurofeedback (NFB) regulation technology based on brain-computer interface (BCI) games to enhance their cognition and concentration and reduce disruptive behaviors. To ensure the ethics of the study and the rights of the participants, this study has undergone ethical review and related ethical consultation.

1) Informed consent

Before the study began, we explained the purpose, methods, potential risks and benefits of the study in detail to all participants and their legal representatives. All participants and their representatives signed an informed consent form to ensure that they fully understood and agreed to participate in this study.

2) Privacy protection

We are committed to strictly protecting the privacy of participants. All collected data will be anonymized, and no personal information will be disclosed in research reports or publicly published papers. All research data will be used only for the purpose of this research and will be strictly stored in a restricted access database.

3) Ethical approval

This study has been approved by the relevant ethics committee (approval number: TMUhMEC2023006). The ethics committee confirmed that the study design was reasonable, risk control measures were in place, and agreed to conduct the study.

2.2. Clinical Trials

2.2.1. EEG Measurement

Using an electroencephalograph (EEG), the patients were kept quiet, awake, and had their eyes closed while the EEG signals were collected after 1 day and 10 days of training. According to the international standard 10 - 20 lead system, 16 electrodes were placed on the scalp at specific locations to ensure comprehensive coverage of brain activity. The acquisition time for each session was 8 minutes, ensuring sufficient data was captured for analysis. The sampling rate was set at 1024 Hz to provide high temporal resolution, allowing for the detailed tracking of neural oscillations. Electrode impedance was maintained below 5 kΩ to ensure high-quality signal acquisition and reduce noise.

The EEG waveforms were specifically extracted from electrodes positioned at FP1 (left forehead), FP2 (right forehead), T3 (left temporal lobe), and T4 (right temporal lobe) regions. These regions were selected due to their relevance in cognitive processing and their potential to reveal significant changes in brain activity related to cognitive functions. The collected data were then processed by the institute of author, utilizing advanced signal processing techniques to analyze EEG complexity.

The complexity of the EEG signals was assessed using sophisticated algorithms that measure the degree of information integration and neural connectivity. This complexity measure is indicative of the brain's functional organization and the efficiency of information processing. The primary metric used to reflect cognitive improvement was the change in the mean of the complexity measurement values. Higher mean values of EEG complexity suggest better integration of information between separable neurons involved in various processing tasks or spatial modes, indicating more efficient neural communication and cognitive function.

By comparing the mean complexity values before and after the training periods, the study aimed to quantify the extent of cognitive improvement. The use of medians in addition to means provided a robust statistical analysis, minimizing the impact of outliers and ensuring the reliability of the results. The detailed methodological approach, including the specific electrode placements, high sampling rate, and rigorous signal processing, lends credibility to the study and supports the validity of the findings related to cognitive dysfunction improvements in the patients.

2.2.2. Statistical Analysis

SPSS25.0 software was used to compare the changes in the MMSE, MoCA, and ADAS-cog scores of patients with cognitive dysfunction before and after neurofeedback training. When the scores of paired statistics conformed to the normal distribution, they were expressed as $x \pm s$, and the paired sample t test method was used for the before-after comparison. When the score results did not conform to the normal distribution, they were expressed as the median (interquartile range) [M (OR)], and the related sample t test was used for the self-comparison before and after training.

3. Results

3.1. Effect of NFB Intervention Based on BCI Games on the Overall Cognitive Function of AD Patients

Patients with cognitive impairment before neurofeedback training were 21.90, 18.60, and 14.72 points, respectively; after training, they were 25.16, 20.98, and 13.45 points, respectively. After neurofeedback training, the total scores of all scales of patients with cognitive impairment were significantly improved ($P < 0.01$) (see Table 2).

3.2. Effects of NFB Intervention Based on BCI Games on Different Cognitive Domains of AD Patients

After neurofeedback training, patients with cognitive impairment showed varying degrees of improvement in most cognitive domains (orientation, memory, language

Table 2. Comparison of scores of each cognitive domain before and after training.

Scale	Cognitive domain	AD patients with cognitive impairment (n = 46)			
		Before training	After training	t value	P value
MMSE	Orientation	8.46 ± 1.12	9.36 ± 1.12	−4.537	<0.001
	Immediate recall	2.60 ± 1.12	3.40 ± 1.12	−1.000	0.322
	Attention and calculation	2.71 ± 1.12	3.70 ± 1.12	−6.256	<0.001
	Recall	1.46 ± 1.12	2.24 ± 1.12	−5.14	<0.001
	Language	6.94 ± 1.12	7.64 ± 1.12	−5.712	<0.001
	MMSE total score	21.90 ± 1.12	25.16 ± 1.12	−16.161	<0.001
MoCA	Visuospatial and executive function	3.33 ± 1.12	3.85 ± 1.12	−1.909	0.062
	Naming	2.34 ± 1.12	2.54 ± 1.12	−2.478	0.017
	Attention	5.14 ± 1.12	5.22 ± 1.12	−5.193	<0.001
	Language	1.53 ± 1.12	1.56 ± 1.12	−3.545	<0.001
	Abstraction	0.60 ± 1.12	1.07 ± 1.12	−2.529	0.015
	Delayed recall	1.36 ± 1.12	2.17 ± 1.12	−6.121	<0.001
	Orientation	5.24 ± 1.12	5.45 ± 1.12	−3.469	<0.001
	MoCA total score	18.60 ± 1.12	20.98 ± 1.12	−10.028	<0.001
ADAS-cog	Word recall	4.26 ± 1.12	4.13 ± 1.12	3.821	<0.001
	Naming	0.29 ± 1.12	0.18 ± 1.12	3.842	<0.001
	Commands	1.18 ± 1.12	1.07 ± 1.12	−0.753	0.455
	Structured practice	0.49 ± 1.12	0.26 ± 1.12	2.438	0.019
	Intentional practice	0.65 ± 1.12	0.24 ± 1.12	5.279	<0.001
	Orientation	0.90 ± 1.12	0.50 ± 1.12	3.967	<0.001
	Word recognition	2.31 ± 1.12	1.59 ± 1.12	5.143	<0.001
	Recall test instructions	1.12 ± 1.12	0.99 ± 1.12	1.000	0.322
	Oral language	0.53 ± 1.12	0.48 ± 1.12	0.573	0.569
	Word finding difficulties	0.48 ± 1.12	0.56 ± 1.12	−0.330	0.743
	Language comprehension	0.96 ± 1.12	0.88 ± 1.12	0.531	0.598
	Attention	1.37 ± 1.12	1.15 ± 1.12	1.400	0.168
	ADAS-cog total score	14.72 ± 1.12	13.45 ± 1.12	16.079	<0.001

and attention) on cognitive assessment scales (MMSE, MoCA and ADAS-cog). Before training, the average scores of patients in MMSE recall, MoCA delayed recall and ADAS recall were 1.46, 1.36 and 4.26 points, respectively. After 10 days of training, the average scores of patients in these three items were 2.24, 2.17 and 4.13 points, respectively. The difference in scores before and after training was statistically significant ($P < 0.01$) (see Table 3), indicating that cognitive training can improve the memory of patients with cognitive impairment.

Before EEG biofeedback, the mean scores of MMSE and MoCA attention were 21.90 ± 1.12 and 18.60 ± 1.12. After 10 days of training, the mean scores of MMSE and MoCA attention were 25.16 ± 1.12 and 20.98 ± 1.12. The difference between the patients before and after training was statistically significant ($P < 0.01$). After training, the scores of patients' attention were significantly improved. In the ADAS-cog attention test, the mean score before training was 14.27, which was reduced to 13.45. There was no statistically significant difference between the scores of ADAS-cog attention before and after training ($P > 0.05$).

3.3. Effect of NFB Intervention Based on BCI Games on EEG Complexity in AD Patients

Table 3. Comparison of EEG complexity before and after training.

Lead	AD patients with cognitive impairment (n = 46)			
	Day 1 $\overline{x \pm s}$	Day 10 $\overline{x \pm s}$	Rank Sum S	P value
FP1	0.08 ± 0.02	0.12 ± 0.02	−27.80	0.0126
FP2	0.08 ± 0.02	0.13 ± 0.02	−179.10	0.0664
F3	0.08 ± 0.02	0.12 ± 0.02	−137.90	0.1496
F4	0.11 ± 0.02	0.12 ± 0.02	−91.20	0.2981

Based on brain-computer interface (BCI) games is an innovative method that aims to improve cognitive function in patients with Alzheimer's disease (AD) by improving the complexity of their EEG. The core mechanism of this method is based on real-time monitoring and adjustment of electroencephalogram (EEG) signals, promoting the brain's self-regulation ability through specific gamified training tasks, thereby affecting the function and structure of neural networks.

Its influence on EEG complexity is as follows:

1) Regulation of EEG signals: Through BCI technology, NFB intervention can capture the EEG activity of AD patients in real time, especially focusing on the relevant indicators of EEG complexity. EEG complexity is considered to be an important indicator of the brain's information processing ability. Higher complexity reflects richer neural network activity and higher information processing ability.

2) Promotion of neuroplasticity: Through NFB training, patients receive immediate feedback from their brains while completing gamified tasks, promoting coordination and connection between brain regions and enhancing the plasticity of

neural networks. This training prompts the brain to adjust its electrical activity patterns to increase EEG complexity, which reflects improved cognitive function.

3) Optimization of information exchange: Improving EEG complexity may enhance information exchange between different brain regions, especially in brain regions related to cognition, such as the prefrontal lobe and temporal lobe. This enhanced information exchange can improve cognitive deficits, especially in memory and attention, two areas closely related to AD patients.

Based on the above mechanism, combined with the comparison of experimental results, the potential for intervention effects can be clearly perceived:

1) Improvement of cognitive function: Research shows that by increasing the complexity of brain electricity, NFB intervention based on BCI games can significantly improve the memory and other cognitive abilities of AD patients. This improvement reflects optimization of brain electrical activity patterns and rehabilitation of cognitive function.

2) Persistence effect: The effect of NFB training is not only significant during the training period, but its improved cognitive function can last for a period of time, which demonstrates the potential of NFB intervention to promote neuroplasticity and long-term cognitive improvement.

3) Objective evaluation indicators: By monitoring objective indicators such as EEG complexity, NFB intervention provides a method to quantitatively evaluate the improvement of cognitive function in AD patients. This data-based approach helps to precisely tailor training regimens to meet the specific needs of individual patients.

In summary, the NFB intervention based on BCI games improved the cognitive function of AD patients, especially in memory and attention, by increasing EEG complexity. The effectiveness and mechanism of this intervention strategy emphasize the key role of neuroplasticity in improving cognitive impairment and provide new perspectives and methods for the treatment of AD and other cognitive disorders.

3.4. Thereby Improving the Patient's Cognition Effect of NFB Intervention Based on BCI Games on Disruptive Behaviors of AD Patients

Neurofeedback (NFB) interventions based on brain-computer interface (BCI) games have demonstrated significant potential in reducing disruptive behaviors in patients with Alzheimer's disease (AD). This innovative approach reduces disruptive behaviors in AD patients by improving cognitive function, specifically enhancing memory and attention. In studies, BCI games optimize brain function by monitoring and adjusting patients' electroencephalogram (EEG) rhythms, specifically by increasing alpha-band activity and improving brain electrical complexity to promote more effective information exchange between neurons. The EEG of AD patients usually shows an increase in low-frequency band (theta and delta) power and a decrease in high-frequency band (alpha and beta) power, which is closely related to the atrophy of cerebral cortex gray matter and the decline of cognitive function.

Through game-based NFB training, patients' brain electrical complexity and alpha-band activity can be improved, thereby improving memory and cognitive abilities. This training method not only has significant benefits on the patient's overall cognitive function, but also particularly improves memory and attention. Compared with traditional feedback therapy, game-based NFB training is more interesting, easier for patients to accept, has higher compliance, and is not affected by education level. Therefore, this method is more suitable for promotion and application, and can significantly reduce patients' disruptive behaviors and improve their quality of life and nursing effects.

In addition, this BCI-based NFB intervention can, to a certain extent, reflect and promote the increase in interneuronal information exchange in the prefrontal area of the brain, especially in the left anterior temporal lobe, which is closely related to the improvement of cognitive function. Although this study has the limitations of small sample size and lack of research on the difference in effects among patients with different degrees of cognitive impairment, BCI-based NFB intervention provides an innovative and effective method for improving the disruptive behaviors of AD patients, especially showing great potential in improving cognitive function. Future studies need to focus on larger sample sizes and long-term follow-up to further verify these preliminary findings and explore the specific effects of NFB training on patients with different degrees of cognitive impairment.

4. Discussion

4.1. Improvement of Cognitive Function

Typical EEG changes in patients with cognitive impairment are slowing of the rhythm, that is, an increase in the power of the low-frequency band (theta and delta) and a decrease in the power of the high-frequency band (alpha and beta). This phenomenon is especially true in the left temporal area and temporoparietal area. Significantly. Some studies have found that the theta frequency band is the earliest to change and the most sensitive EEG biomarker in the pathological process of AD. Compared with normal elderly people, patients with AD have higher power in the theta frequency band in the temporal lobe and parieto-occipital lobe, while reduced power in the α-band in the parieto-occipital lobe and frontal and temporal lobes.

At the same time, the slowdown of resting-state EEG rhythm in AD patients does not exist in isolation. It can reflect the degree of atrophy of the gray matter in the cerebral cortex and the patient's cognitive function. That is, the smaller the volume of the patient's gray matter, the more likely it is to be accompanied by delta The increase in power and the decrease in alpha power lead to cognitive decline. Based on the above research foundation, it is speculated that EEG-based neurofeedback will help improve the memory performance of patients with cognitive impairment. Research by Lavy's team found that the neurofeedback training system improves the cognitive abilities, especially memory, of patients with

MCI.

And further research also found that compared with the negative control group, using an electroencephalogram-based neurofeedback system to increase the activity level of the alpha band can significantly improve the memory performance of MCI patients, and this improvement lasted for at least 1 year. months.

Compared with boring feedback treatment, the game-based neurofeedback training system can improve the cognitive ability of healthy elderly subjects and amnestic MCI patients, and is easier to promote. This study uses a game-based electroencephalogram neurofeedback system, which is highly interesting, easier for patients to accept, not affected by education level, and has high compliance. It is not only conducive to the improvement of patients' overall cognitive function, but also improves patients' memory, Improvements in concentration are even more pronounced. At the same time, there is no statistical difference in the ADAS-cog attention part scores of patients before and after training, which may be due to the strong subjectivity and lack of quantification of the attention part of the scale.

4.2. Increased EEG Complexity

The EEG signal is actually an unstable, nonlinear, complex signal generated by the interaction of different neural sources (oscillations). In theory, the higher the complexity of the EEG signal, the higher the integration of information by separate neurons in different processing tasks or in different spatial modes, and the lower the complexity, the lower the information exchange between separate neurons.

Several studies have confirmed that AD and MCI patients have reduced EEG complexity, indicating that the decline in patients' cognitive function may be related to the reduction of information exchange between neurons. This study found that the complexity of the left frontal area of patients increased through EEG-based neurofeedback training. The left frontal area is the dominant hemisphere related to cognition, which may reflect the increase in information exchange between neurons in the left anterior temporal lobe during EEG-based neurofeedback training, and the patient's cognitive function has improved.

Therefore, this study conducted game-based neurofeedback training on patients with cognitive impairment to increase the information exchange function of neurons in the left anterior temporal lobe. The main limitation of this study is the small sample size. In exploring the improvement of patients' cognitive function by EEG neurofeedback training, more large samples and long-term follow-up studies are needed to improve the persuasiveness of this hypothesis. In addition, since this study did not grade the severity of patients with cognitive impairment (the type of dementia is more concerned), it is impossible to further explore the improvement effect of brain neurofeedback training on cognitive symptoms in patients with different degrees of cognitive impairment.

4.3 Reduction of Disruptive Behaviors

Neurobiofeedback (NBF) interventions based on brain-computer interfaces (BCI) have shown significant potential to target disruptive behaviors in patients with Alzheimer's disease (AD). This intervention reduces disruptive behaviors in AD patients by improving cognitive function, especially by enhancing memory and attention. By monitoring and adjusting the patient's electroencephalogram (EEG) rhythm, NBF training aims to optimize brain function, specifically by increasing alpha-band activity and improving EEG complexity to promote more effective information exchange between neurons.

Studies have shown that the EEG of AD patients exhibits specific changes, such as a slowing of rhythm, especially in the left temporal and temporoparietal regions, which is manifested as an increase in low-frequency (θ and δ) power and a decrease in high-frequency (α and β) power. These changes are associated with atrophy of cortical gray matter and decreased cognitive function. Game-based NBF training can improve patients' EEG complexity and α-band activity, thereby improving memory and cognitive ability. This training method is not only beneficial to the patient's overall cognitive function, but also has a particularly significant improvement in memory and attention, and has higher compliance and acceptance.

In addition, this BCI-based NBF intervention can, to a certain extent, reflect and promote the increase in interneuronal information exchange in the prefrontal area of the brain, especially in the left anterior temporal lobe, which is closely related to the improvement of cognitive function. Despite the limitations of small sample size and lack of research on the difference in effects among patients with different degrees of cognitive impairment, BCI-based NBF intervention provides an innovative and effective method for improving disruptive behaviors in AD patients, especially showing great potential in improving cognitive function. Future studies need to focus on larger sample sizes and long-term follow-up to further verify these preliminary findings and explore the specific effects of NBF training on patients with different degrees of cognitive impairment.

5. Summary

Alzheimer's disease (AD) is a neurodegenerative disorder that leads to significant impairments in memory, cognition, language, and even personality changes as it progresses. Disruptive behaviors (DB) in AD patients are abnormal behaviors resulting from cognitive impairments. Clinical studies indicate that most AD patients exhibit DBs, greatly complicating their management and care. Consequently, it is crucial for clinical practice to identify the factors influencing DBs in AD patients and develop targeted interventions to reduce their incidence.

This study's linear regression analysis identified several risk factors for increased levels of DBs in AD patients, including age ≥ 60 years, hypertension, diabetes, coronary heart disease, poor self-care ability, and lack of psychiatric treatment. Reduced self-care ability, a primary symptom of AD, significantly increases the complexity of care. As AD progresses, patients experience a decline in cognition, intelligence, and memory, leading to reduced self-care abilities and an increased likelihood of resistance and violent behavior, further complicating caregiving.

To address this, patients should receive proper training in daily self-care activities. Clinicians can guide patients to complete these behaviors independently, thereby improving their self-care abilities and slowing disease progression. Older patients are particularly challenging to manage due to increased dependency and cognitive decline. Thus, clinical staff should prioritize attention and care for elderly patients to mitigate the incidence of DBs.

Additionally, AD patients with concurrent chronic diseases exhibit higher DB incidence rates, with caregiving difficulty escalating with the number of comorbid conditions. Hypertension, coronary heart disease, and diabetes not only induce AD but also exacerbate its progression. Chronic diseases contribute to cerebrovascular damage, impairing cognitive function. The compounded effects of multiple chronic conditions worsen cerebrovascular damage, leading to a higher incidence of DBs. For AD patients with comorbid chronic diseases, clinicians should provide health education and professional care guidance for caregivers while closely monitoring the patient's condition to delay disease progression.

Lack of psychiatric treatment is a significant factor contributing to disease progression, which increases the difficulty of management and care. A combination of pharmacological and non-pharmacological treatments can effectively alleviate mental and behavioral symptoms, reducing caregiving challenges. Conversely, the absence of psychiatric treatment leads to continued cognitive decline, worsening mental and behavioral symptoms, and higher DB incidence.

While the study provides valuable insights into the factors influencing DBs in AD patients, several limitations must be acknowledged. The sample size may not be representative of the broader AD patient population, potentially limiting the generalizability of the findings. Additionally, the cross-sectional nature of the study precludes establishing causal relationships between identified risk factors and DBs. Longitudinal studies are needed to confirm these associations and better understand the temporal dynamics of DBs in AD patients.

Furthermore, the reliance on caregiver reports and clinical observations may introduce bias, as these measures can be subjective. Future studies should incorporate objective assessments, such as neuroimaging and biomarkers, to validate the findings. Finally, the study did not account for potential confounding variables, such as socioeconomic status and caregiver burden, which could influence DBs and caregiving outcomes.

6. Implications and Future Directions

The findings highlight the need for comprehensive care strategies that address both medical and psychosocial aspects of AD. Interventions should focus on improving self-care abilities, managing chronic comorbidities, and ensuring access to psychiatric treatment. Healthcare providers should be trained to recognize and address DBs early, using evidence-based approaches to mitigate their impact.

Future research should explore the effectiveness of specific interventions, such as tailored self-care training programs and integrated chronic disease management, in reducing DBs. Additionally, studies should investigate the role of emerging technologies, such as neurofeedback and digital therapeutics, in enhancing cognitive function and reducing DBs in AD patients.

By addressing these limitations and expanding research efforts, we can develop more effective strategies to manage DBs in AD patients, ultimately improving their quality of life and easing the burden on caregivers.5. Summary.

Funding

Funded by Tianjin Medical University's Municipal Undergraduate Innovation and Entrepreneurship Training Program; Item Number: 202310062047.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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