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Article

Impacts and therapeutic effects of biofeedback in painting creation on the neural network of children with autism

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Abstract: Objective: To explore the effects of different external treatment methods on biofeedback stimulation in patients with autism, analyze the impact of different biofeedback stimuli on the transmission of neural network signals in patients, and evaluate the therapeutic effects on autism patients. **Method:** 120 autistic patients under the age of 13 were selected and divided into a control group and an experimental group. The experimental group patients were intervened with a combination of painting therapy and traditional treatment. The control group patients were only intervened with traditional therapy. During the experiment, relevant instruments were used to collect changes in the patient's eye electrical signals during the treatment process. The relationship between changes in eye electrical signals and patient efficacy was analyzed. **Results:** After four courses of treatment, the experimental group demonstrated a significant increase in the infant/junior high school social and biological competence scale and goals achievement and learning scale ($p < 0.001$), indicating that painting therapy had a good therapeutic effect on children with autism. During the treatment process of painting therapy, the total electrooculogram approximate entropy of the patient's eye electrical activity significantly decreased ($p < 0.001$). During the painting process, the patient's attention and state were more focused. **Conclusion:** The biofeedback signals of children with autism undergoing painting therapy show that the patient's attention is more focused and their concentration is higher than usual. Painting therapy can promote the further development of neural networks in children with autism by intervening in their bioelectric signals.

Keywords: painting creation; biofeedback; autism; neural network; therapeutic effects

1. Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental disorder characterized by social communication disorders, repetitive behavior, and sensory abnormalities [1]. In recent years, with the rising incidence rate of autism, its impact on society and families has become increasingly significant. It has become one of the important challenges in the field of global public health. Although traditional intervention methods such as behavioral therapy and medication have to some extent alleviated symptoms in patients with autism, existing methods still have limitations in improving patients' social skills and emotional regulation [2,3]. Art therapy, especially painting therapy, has received widespread attention due to its ability to provide a non-verbal emotional expression pathway for individuals with autism. Painting can not only help individuals with autism establish connections with the outside world but also promote their psychological and emotional stability [4,5]. Moreover, biofeedback technology, as an emerging intervention method, helps patients regulate their emotions and behaviors by monitoring and providing real-time feedback on their physiological signals. In recent years, technologies like Heart Rate Variability Biofeedback (HRVB) and electrooculography biofeedback have shown potential application value in autism intervention [6]. Therefore, to achieve a more comprehensive intervention effect, the study combines biofeedback technology with art therapy and explores its impact and therapeutic effects on the neural network of children with autism. The innovation of the research lies in the combination of painting therapy and biofeedback technology, which not only provides a new perspective for autism intervention but also provides an important basis for further understanding the neurophysiological mechanisms of autism.

2. Related works

With the rise of the incidence rate of autism, relevant studies have emerged to explore effective intervention methods and evaluation tools. These studies cover multiple fields, from physiological regulation to artistic creation to emotion recognition and painting evaluation, providing new perspectives and methods for interventions and support for individuals with autism. Thoen A et al. designed a single-blind, randomized, sham-controlled pilot trial to address the low cardiac vagal nerve regulation level in adolescents with autism. A total of 44 adolescents with autism were included, with 24 receiving supervised HRVB training and 20 receiving sham training. After supervised HRVB training, the vagus nerve regulation of the heart in adolescents significantly increased, heart rate increased, and cortisol levels decreased. However, these effects disappeared during follow-up, and there was no significant improvement in psychosocial function. Family-based HRVB training was feasible and reduced stress symptoms in adolescents, but compliance was poor [7]. Regarding the subjective relationship among individuals with autism in artistic creation, Chérel critically analyzed scientific literature to explore the conditions under which graphic creativity could serve as an impulse localization tool among individuals with autism. A multidimensional space was built. Individuals with autism, such as Iris Grace, established connections with the world through painting and developed unique subjective motivations. Painting not only helped them regulate their impulses but also promoted connection with the world [8]. Hu proposed an emotional performance evaluation system on the basis of artificial intelligence to address the emotion recognition and intervention for children with autism. This system effectively judged the emotions of children with autism and helped teachers evaluate student performance by analyzing classroom learning data. The research results indicated that spatiotemporal graph convolutional networks and random forests performed well in action recognition and expression recognition, respectively. In addition, painting could serve as a rehabilitation therapy for children with autism, helping them regulate their emotions [9]. Shen et al. proposed an intelligent evaluation system based on machine learning to address the insufficient professionals in painting assessment for children with autism. The system identified portrait sketch components, automatically segmented portrait sketch components, and designed an evaluation model. The experimental results showed that the system could effectively identify autism tendencies and accurately evaluate children's autism tendencies through the "drawing person" experiment [10].

In summary, significant progress has been made in the intervention and assessment of autism in current research. From the perspective of physiological regulation, HRVB training has shown potential benefits in regulating the vagus nerve of the heart in adolescents with autism. In the field of artistic creation, painting can help individuals with autism establish a connection with the world and form a unique subjective drive. The system, on the basis of machine learning and artificial intelligence, provides new technological means for emotion recognition and painting evaluation of children with autism. However, there are still some shortcomings in existing research, lacking systematic studies on the comprehensive application of multiple intervention methods. Therefore, the research aims to systematically evaluate the impact of painting therapy and biofeedback technology on the neural networks of children with autism and its therapeutic effects in order to make up for the shortcomings of existing research.

3. Data and methods

3.1. General information

A basic situation analysis was conducted on 120 autistic patients under the age of 13. These patients are randomly divided into a Control Group (CG) and an Experimental Group (EG), with 60 people in each one. **Table 1** displays the general information. No obvious differences existed between the CG and the EG on gender ratio, age, height, weight, and degree of autism (p > 0.05). The gender ratio, age distribution, average height and weight of the two groups were similar. No obvious difference existed in the autism score.

Table 1. Comparison of the general data of the tested children.

Groups Total cases	Control group	Experimental group
Male (example)	60	60
Female (example)	42	38
Age (years)	18	22
Height (cm)	4.5 ± 1.15	4.6 ± 1.14
Weight (kg)	95.5 ± 9.61	96.8 ± 10.87
Degree of autism (score)	15.9 ± 2.44	17.0 ± 3.32
Groups Total cases	85.7 ± 3.51	86.6 ± 3.89

3.2. Experimental route design

Firstly, children who satisfy the diagnostic criteria for autism were randomly selected and divided into an EG and a CG, with 60 people in each one. The EG received a combination of painting therapy and traditional intervention, while the CG only received traditional intervention. The intervention period was 16 weeks, 3 times a week, with each session lasting 60 min. Before intervention, at weeks 8 and 16, children's eye electrical signals were recorded using an eye electrical device, and their social skills, language expression, and emotional control were evaluated using a behavioral scale. During the experiment, the focus was on monitoring indicators such as Total Electrooculogram Approximate Entropy (TEOAE) and analyzing their relationship with children's attention span and behavioral improvement. Finally, by comparing two sets of data, the positive effects of combining painting creation with biofeedback on the neural network and behavior of children with autism were explored. The entire experimental route design is shown in **Figure 1**.

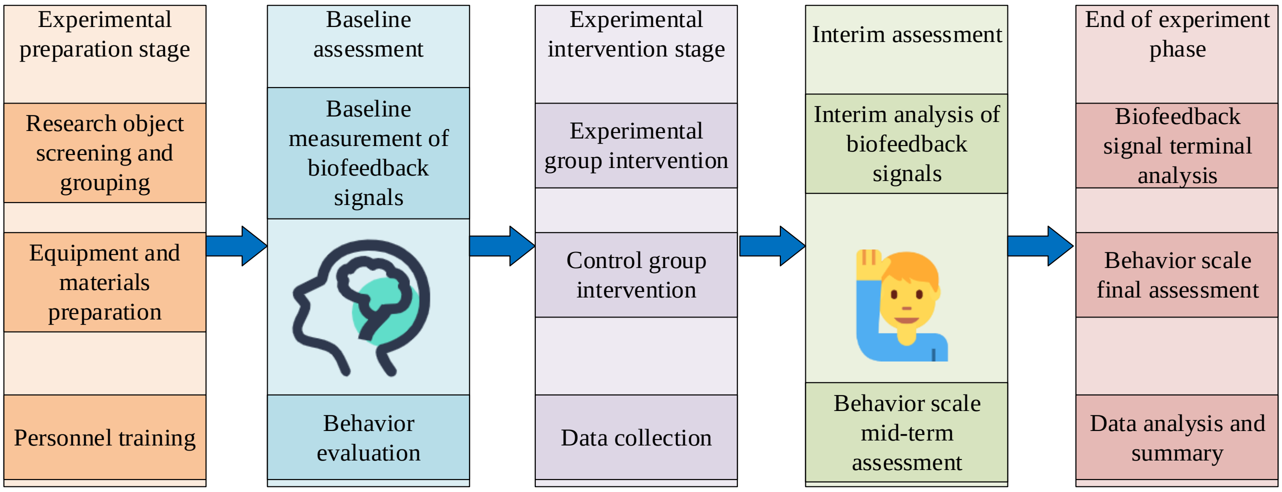

Figure 1. Experimental route design.

3.3. Research method

The study adopts a randomized controlled experimental design, selecting 120 children with autism aged between 6 and 12 years old and randomly dividing them into an EG and a CG, each having 60 children. The EG introduces painting creation intervention on the basis of traditional intervention. Guided by professional therapists, children express emotions and ideas during the painting process. The selection of the control group and the use of a specific traditional therapy are intended to provide a valid baseline for comparison to evaluate the relative effectiveness of the intervention in the experimental group. Regular rehabilitation training has been shown to have some effect on children with autism, improving their communication skills, social interaction, and daily living skills. Using these traditional therapies as controls ensures comparability and reproducibility of study results, allowing for a more accurate assessment of the additional efficacy of the intervention in the experimental group. The painting task includes two types: A free creation task, which allows the participants to draw according to their own wishes and emotions, and a structured task, which provides specific themes or guidance by the therapist, such as drawing specific scenes or objects, to guide the participants to make targeted creations; The selection of materials includes white sketch paper with a size of about 80, oil painting sticks of 24 or 36 colors, crayons, colored pencils, colored lead, as well as 2B pencils, oil drawing pens, and gold and silver markers, which can meet the drawing needs and preferences of different participants and are easy to operate and clean; Instructions to participants include clearly introducing the purpose and process of painting therapy to participants before painting, encouraging them to express their feelings and ideas freely, and informing them that they can always seek help or feedback from the therapist during the painting process; the control of environmental variables included painting therapy in a quiet, comfortable, and softly lit room, lit with natural or soft artificial light to avoid direct glare, and noise levels kept to a minimum to reduce outside distractions and ensure participants could focus on painting. At the same time, biofeedback devices such as electroencephalography and electrooculography are used to monitor children's neurophysiological signals in real time, including changes in frequency and amplitude of brainwaves, stability of eye electrical activity, etc., to evaluate their attention and emotional state stability. The CG only receives traditional intervention and does not involve painting creation. The research period is 16 weeks, with 3 interventions per week and each intervention lasting 60 min. The intervention includes painting creation, emotional guidance, and biofeedback monitoring. Behavioral assessments are conducted on two groups before intervention (baseline), during intervention (week 8), and after intervention (week 16), using standardized scales to evaluate their social skills, language expression, emotional control, and other behavioral manifestations. Their biofeedback indicators, such as TEOAE, blink frequency, and α and β wave changes in brainwaves of children during the process of painting creation, are recorded and analyzed. By comparing the biofeedback signals and behavioral assessment results of two groups before and after intervention, the impact of biofeedback on the neural network of autistic children during the painting creation process and its therapeutic effect are analyzed.

The Amplifier Module uses the PLUX bio-signal acquisition system; the model is the PLUX Bio Amplifier Module; the sampling rate is up to 2000 Hz; there is a built-in adjustable high-pass and low-pass filter to effectively remove the noise signal; it uses Ag/AgCl electrodes to ensure the stable transmission of the signal; and it supports wireless data transmission. The transmission distance can be up to 10–15 m, which is convenient for the subject to move freely during the painting process. The electrodes are placed at the inner and outer canthus corners of the subject's eyes to record the potential changes caused by eye movements. The skin is cleaned and hair is removed before the electrodes are placed to reduce the skin impedance and ensure good contact between the electrodes and the skin.

The AMTI OR6-X-OP series biomechanical force-measuring platform was used to test postural stability. During the test, the subjects held a static standing position on the force measuring platform, with their feet naturally spaced shoulder-width apart and hands at their sides, and held a static standing position for 60 s. The postural stability of the subject is assessed by analyzing the displacement and velocity of the Center of Pressure locus (COP). The displacement range and moving speed of COP are key indicators of postural stability. A smaller COP displacement range and lower moving speed usually indicate better postural stability. The test method conforms to the relevant standards of the International Organization for Standardization (ISO) on the assessment of human postural stability (ISO 2631-1:1997), ensuring the reliability and repeatability of the test results.

Muscle tension was measured using surface electromyography (sEMG) technology, and data was collected using the Biomomentum MACH-1 Mechanical Test and analysis system. In the process of measurement, the main motor muscle groups of the subjects were selected, such as quadriceps, tibialis anterior muscle, deltoid muscle, etc., and the EMG signal was recorded. The Root Mean Square (RMS) value of the EMG signal was calculated as a specific index to evaluate muscle tension. Before data collection, the subject's skin should be cleaned and hair removed to reduce skin impedance and ensure good contact between electrodes and skin. The electrodes are pasted according to the international standard placement method to ensure the accuracy and repeatability of the measurement results.

3.4. Observation indicator

Electroencephalogram (EEG) devices continuously record the brainwave activity of children during drawing, with a focus on EEG bands related to attention concentration and emotional states, such as changes in power spectral density of θ waves, α waves, and β waves [11]. Among them, the increase of θ waves is usually associated with a relaxed state, while the enhancement of β waves may indicate higher attention concentration. In addition, the Heart Rate Variability (HRV) is incorporated into the monitoring scope. Analyzing the ratio of low-frequency and high-frequency components reflects children's autonomic nervous system activity and emotional regulation ability [12]. Standardized Behavior Scale, Autism Behavior Checklist (ABC), Social Adaptation Scale (SAC), Infant/Junior High School Social and Biological Competence Scale (IBS/SC), and Goal Achievement and Learning Scale (GOALS) are adopted. Children's behavior is quantitatively evaluated before, during (week 8), and after (week 16) the intervention. Serum levels of brain-derived neurotrophic factor (BDNF) were detected by enzyme-linked immunosorbent assay (ELISA). At the same time, the activity of superoxide dismutase (SOD) was detected by the xanthine oxidase method. The chromogenic agent was added and placed at room temperature for 10 min. The content of SOD was detected by colorimetry at 450 nm. In addition, the level of malondialdehyde (MDA) was detected by thiobarbituric acid colorimetry, and the absorbance value was measured by zero adjustment of distilled water, and the MDA content was calculated.

3.5. Statistical method

The biofeedback signals collected in the study, such as brainwave power spectral density, TEOAE, HRV, and scoring data from ABC, are processed and analyzed using professional statistical software. For quantitative data, descriptive statistical analysis is used to calculate statistical measures such as mean, standard deviation, median, etc., in order to comprehensively understand the distribution characteristics of the data. When comparing the differences between the EG and the CG, an independent sample *t*-test is used. For repeated measurement data, such as changes in behavior scale scores before, during, and after intervention, the repeated measurement ANOVA is used to evaluate the temporal and inter-group effects of intervention measures. In addition, to investigate the correlation between biofeedback signals and behavioral improvement, Pearson correlation analysis is used to determine the linear or nonlinear relationship between the two. All statistical tests are significant at $p = 0.05$ to determine the statistical significance.

4. Results

4.1. Patient efficacy analysis

4.1.1. Analysis of ABC and SAC in children with autism

The analysis of the ABC and SAC for children with autism is shown in **Figure 2**. After receiving painting therapy combined with traditional intervention, the EG demonstrated obvious decreases in ABC scores and improvements in SAC scores. The

CG only received traditional intervention, with a smaller improvement and a significant difference ($p < 0.05$).

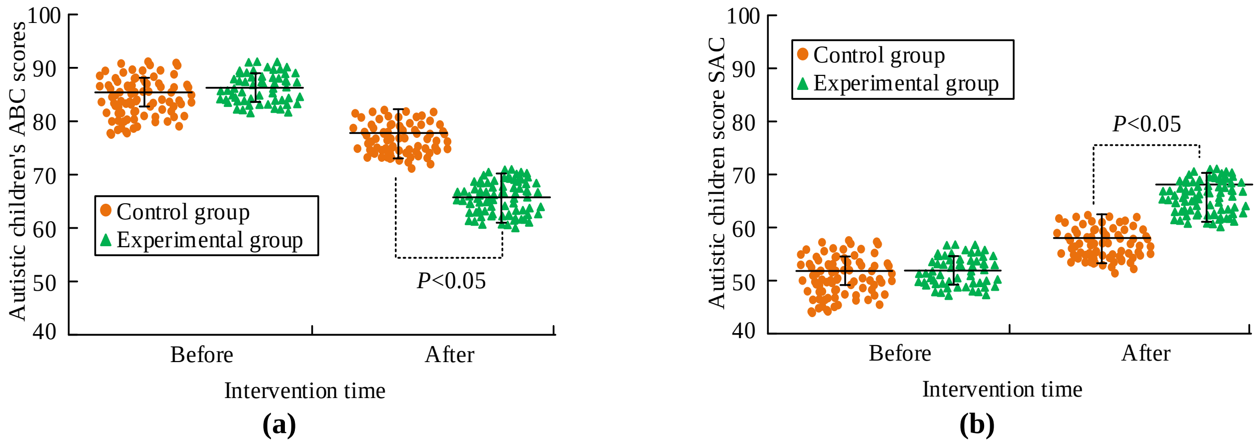

Figure 2. Comparison of ABC and SAC scores before and after treatment, **(a)** ABC analysis of autistic children; **(b)** SAC analysis of autistic children.

4.1.2. Analysis of IBS/SC and GOALS in children with autism

Figure 3 displays IBS/SC and GOALS scores between the EG and the EG before and after treatment. The CG only received traditional intervention, and their scores improved to a certain extent after treatment, but the improvement was small and had a significant difference ($p < 0.05$). After receiving painting therapy combined with traditional intervention, the EG demonstrated improvements in the scores of both scales, with a significant difference ($p < 0.05$).

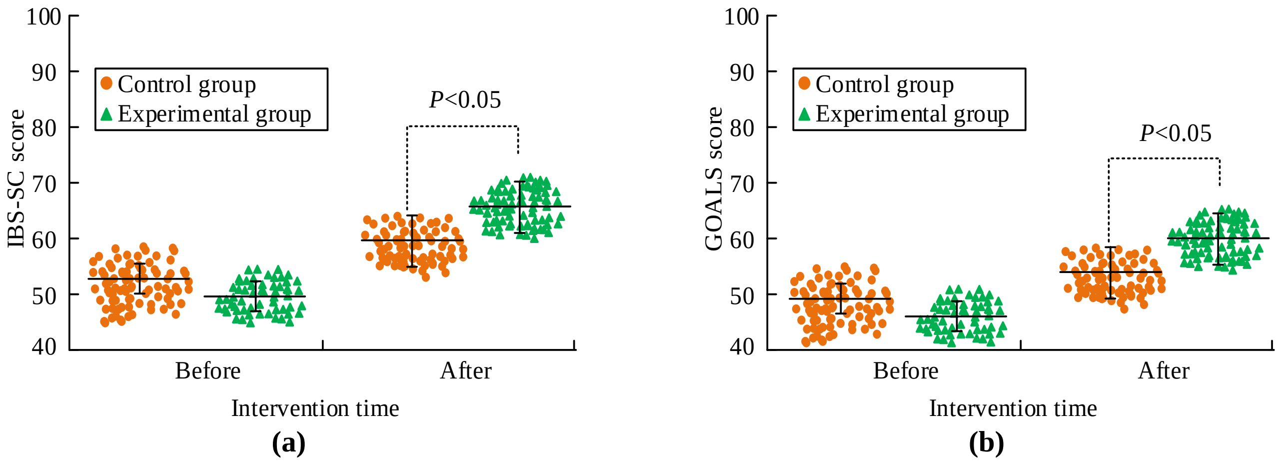

Figure 3. Comparison of IBS/SC and GOALS scores before and after treatment, **(a)** ABC analysis of autistic children; **(b)** SAC analysis of autistic children.

4.1.3. Analysis of motor ability in children with autism

Table 2 displays the motor abilities of autistic children in the EG and the CG before and after treatment. The CG exhibited obvious improvements in mobility skills before and after treatment ($p = 0.038$), but the improvement was relatively small. The EG exhibited improvements before and after treatment ($p < 0.001$). The CG showed a slight improvement in operational skills before and post-therapy ($p = 0.062$), but did not reach a significant level. The EG showed significant improvement before and after treatment ($p < 0.001$). No obvious difference existed between the two groups before treatment ($p > 0.05$). After treatment, the EG exhibited improvements in both mobility skills and operational skills compared to the CG ($p < 0.001$).

Table 2. Analysis of motor ability of autistic children before and after treatment.

Groups	Control group		Experimental group		Comparison between groups	
Point in time	**Before treatment**	**Post-treatment**	**Before treatment**	**Post-treatment**	**Before treatment**	**Post-treatment**
Mobility skills score	20.5 ± 3.00	22.0 ± 2.80	21.0 ± 3.10	25.5 ± 2.50	/	/
Operational skills score	17.0 ± 2.50	18.5 ± 2.40	17.5 ± 2.60	22.0 ± 2.30	/	/
T-value (Mobility skills)	/	2.10	/	4.50	0.80	3.60
p-value (Mobility skills)	/	0.038	/	< 0.001	0.425	< 0.001
T-value (Operational skills)	/	1.90	/	4.20	0.60	3.40
p-value (Operational skills)	/	0.062	/	< 0.001	0.550	< 0.001

4.1.4. Analysis of integration abilities in children with autism

The comparison of integration ability between the EG and the CG of autistic children before and after treatment is shown in **Figure 4**. The vestibular balance of CG showed improvement before and after treatment ($p = 0.045$), but the improvement was relatively small. The EG exhibited obvious improvement before and after treatment ($p < 0.001$). The tactile function of the CG exhibited slight improvement before and after treatment ($p = 0.055$) but did not reach a significant level. The EG exhibited significant improvement before and after treatment ($p < 0.001$). The proprioception of CG exhibited a slight improvement before and after treatment ($p = 0.038$). The EG demonstrated improvements before and after treatment ($p < 0.001$). No obvious difference existed between the two groups before treatment ($p > 0.05$). Post-therapy, the EG exhibited improvements in vestibular balance, tactile function, and proprioception compared to the CG ($p < 0.001$).

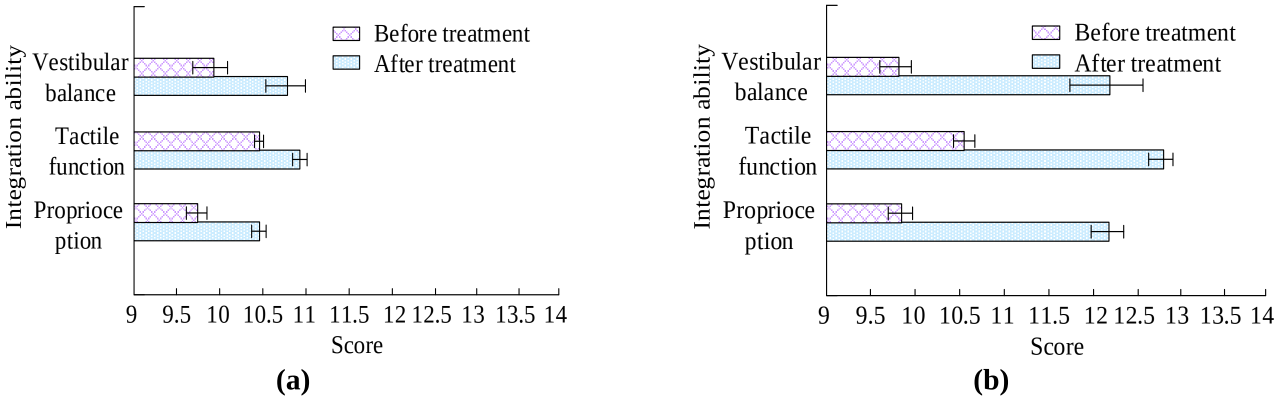

Figure 4. Comparison of the integration ability of autistic children before and after treatment, **(a)** control group; **(b)** experimental group.

4.2. Analysis of patient biofeedback signals

4.2.1. TEOAE analysis of children with autism

The TEOAE analysis of autistic children in the EG and CG before and after treatment is shown in **Table 3**. The TEOAE of the CG showed a slight decrease before and after treatment ($p = 0.138$) but did not reach a significant level. The EG showed a significant decrease ($p < 0.001$). No obvious difference between the two groups before treatment ($p = 0.550$), while the improvement in the EG exceeded that in the CG post-therapy ($p < 0.001$). The combination of painting therapy and biofeedback significantly improves the concentration of attention in children with autism. Especially in the inter-group comparison post-therapy, the improvement in the EG was more significant.

Table 3. Analysis of TEOAE of autistic children before and after treatment.

Groups	Time	TEOAE score	*T*-value	*p*-value
Control group	Before treatment	1.25 ± 0.20	/	/
	Post-treatment	1.18 ± 0.18	1.50	0.138
Experimental group	Before treatment	1.27 ± 0.22	/	/
	Post-treatment	0.95 ± 0.15	4.80	< 0.001
Comparison between groups	Before treatment	/	0.60	0.550
	Post-treatment	/	3.90	< 0.001

4.2.2. EEG analysis of children with autism

Table 4. EEG biofeedback analysis of children with autism before and after treatment.

Groups	Control group		Experimental group		Comparison between groups	
Point in time	**Before treatment**	**Post-treatment**	**Before treatment**	**Post-treatment**	**Before treatment**	**Post-treatment**
Alpha wave power spectral density	10.2 ± 1.50	10.5 ± 1.40	10.5 ± 1.60	12.0 ± 1.40	/	/
Beta wave power spectral density	8.5 ± 1.20	8.7 ± 1.10	8.8 ± 1.30	10.5 ± 1.20	/	/
Theta wave power spectral density	6.8 ± 0.90	6.9 ± 0.85	6.7 ± 0.95	6.0 ± 0.80	/	/
T-value (alpha wave)	/	0.80	/	4.20	0.60	3.50
p-value (alpha wave)	/	0.425	/	< 0.001	0.550	< 0.001
T-value (beta wave)	/	0.60	/	4.50	0.70	3.80
p-value (beta wave)	/	0.550	/	< 0.001	0.485	< 0.001
T-value (theta wave)	/	0.50	/	3.80	0.80	3.30
p-value (theta wave)	/	0.620	/	< 0.001	0.425	< 0.001

The EEG biofeedback analysis of autistic children in the EG and CG before and after treatment is shown in **Table 4**. The changes in α wave power spectral density before and after treatment were not significant in the CG ($p = 0.425$). The EG showed a significant increase before and after treatment ($p < 0.001$). The CG showed no obvious change in beta wave power spectral density before and after treatment ($p = 0.550$). The EG showed a significant increase before and after treatment ($p < 0.001$). No obvious change in the power spectral density of the θ wave before and after treatment in the CG ($p = 0.620$). The EG showed a significant decrease before and after treatment ($p < 0.001$). There was no significant difference between the two groups before treatment ($p > 0.05$). Post-therapy, the EG exhibited improvements in α wave, β wave, and θ wave compared to the CG ($p < 0.001$).

4.2.3. Analysis of respiratory biofeedback in children with autism

The respiratory biofeedback analysis of autistic children in the EG and CG before and after treatment is shown in **Table 5**. The respiratory rate of the CG showed a slight decrease before and after treatment ($p = 0.138$) but did not reach a significant level. The EG showed a significant decrease before and after treatment ($p < 0.001$). No obvious change existed in respiratory depth before and after treatment in the CG ($p = 0.235$). The EG showed a significant increase before and after treatment ($p < 0.001$). The respiratory rhythm of the CG showed a slight improvement before and after treatment ($p = 0.075$) but did not reach a significant level. The EG exhibited improvements before and after treatment ($p < 0.001$). No obvious difference existed between the two groups before treatment ($p > 0.05$). Post-therapy, the EG exhibited improvements in respiratory rate, respiratory depth, and respiratory rhythm compared to the CG ($p < 0.001$).

Table 5. Respiratory biofeedback analysis of children with autism before and after treatment.

Groups	**Control group**		**Experimental group**		**Comparison between groups**	
Point in time	**Before treatment**	**Post-treatment**	**Before treatment**	**Post-treatment**	**Before treatment**	**Post-treatment**
Respiratory rate (times/min)	20.5 ± 2.00	19.5 ± 1.80	20.8 ± 2.10	17.0 ± 1.50	/	/
Respiratory depth (cm)	2.5 ± 0.50	2.6 ± 0.45	2.4 ± 0.55	3.0 ± 0.40	/	/
Respiratory rhythm	70.0 ± 5.00	72.0 ± 4.50	71.0 ± 5.20	80.0 ± 4.00	/	/
T-value (respiratory rate)	/	1.50	/	4.50	0.80	3.60
p-value (respiratory rate)	/	0.138	/	< 0.001	0.425	< 0.001
T-value (breathing depth)	/	1.20	/	4.00	0.60	3.80
p-value (breathing depth)	/	0.235	/	< 0.001	0.550	< 0.001
T-value (respiratory rhythm)	/	1.80	/	5.00	0.70	4.20
p-value (respiratory rhythm)	/	0.075	/	< 0.001	0.485	< 0.001

4.2.4. Analysis of heart rate biofeedback in children with autism

The heart rate biofeedback analysis of autistic children in the EG and CG before and after treatment is shown in **Table 6**. The resting heart rate of the CG showed a slight decrease before and after treatment ($p = 0.235$) but did not reach a significant level. The EG showed decreases before and after treatment ($p < 0.001$). The HRV CG showed a slight improvement before and after treatment ($p = 0.138$) but did not reach a significant level. The EG exhibited improvements before and after treatment ($p < 0.001$). No obvious difference existed between the two groups before treatment ($p > 0.05$). Post-therapy, the EG exhibited improvements in both resting heart rate and HRV dimensions compared to the CG ($p < 0.001$).

Table 6. Heart rate biofeedback analysis of children with autism before and after treatment.

Groups	Point in time	Resting heart rate (times/min)	HRV	*T*-value (resting heart rate)	*p*-value (resting heart rate)	*T*-value (HRV)	*p*-value (HRV)
Control group	Before treatment	95.0 ± 5.00	50.0 ± 5.00	/	/	/	/
	Post-treatment	93.5 ± 4.80	52.0 ± 4.50	1.20	0.235	1.50	0.138
Experimental group	Before treatment	96.0 ± 5.20	51.0 ± 5.10	/	/	/	/
	Post-treatment	88.0 ± 4.50	58.0 ± 4.00	4.80	< 0.001	4.20	< 0.001
Comparison between groups	Before treatment	/	/	0.70	0.485	0.60	0.550
	Post-treatment	/	/	3.80	< 0.001	3.50	< 0.001

4.2.5. Biomarker detection results before and after treatment

The test results of BDNF level, SOD activity, and MDA level before and after treatment are shown in **Table 7**. After treatment, the levels of BDNF, SOD activity, and MDA in the experimental group were significantly changed, with statistically significant differences compared with the control group ($p < 0.001$), indicating that painting therapy can promote the development of neural networks in children with autism by affecting the expression of these biomarkers.

Table 7. Biomarker detection results before and after treatment.

Group	Experimental group	Control group
Number of cases	60	60
Pre-treatment BDNF level (pg/mL)	12,000.5 ± 2500.3	11,800.1 ± 2300.5
BDNF level after treatment (pg/mL)	8000.2 ± 1500.6	11,500.4 ± 2100.7
p-value	< 0.001	0.235
SOD activity before treatment (U/mL)	120.5 ± 20.3	118.0 ± 19.5
SOD activity after treatment (U/mL)	150.2 ± 25.6	120.4 ± 22.3
MDA level before treatment (nmol/mL)	10.5 ± 2.1	10.8 ± 2.3
MDA levels after treatment (nmol/mL)	8.0 ± 1.5	10.2 ± 2.0
p-value	< 0.001	0.135

4.2.6. Analysis of long-term effects on autistic children

An analysis of the long-term effects on children with autism is shown in **Table 8**. At 1 and 3 months after intervention, IBS/SC score, GOALS score, BDNF level, SOD activity, and MDA level of the experimental group were significantly improved, and the differences were statistically significant compared with the control group ($p < 0.001$). This suggests that painting therapy is not only effective in the short term, but its benefits are also sustainable in the long term.

Table 8. Analysis of long-term effects in children with autism.

Project	**group**	**Before treatment (mean ± standard deviation)**	**3 months after intervention (mean ± standard deviation)**	***p*-value**
IBS/SC rating	Experimental group	15.9 ± 2.44	22.0 ± 3.50	< 0.001
	Control group	15.9 ± 2.44	17.5 ± 3.00	0.235
GOALS score	Experimental group	85.7 ± 3.51	92.0 ± 4.20	< 0.001
	Control group	85.7 ± 3.51	88.0 ± 3.90	0.138
BDNF level (pg/mL)	Experimental group	12,000.5 ± 2500.3	7500.1 ± 1300.5	< 0.001
	Control group	11,800.1 ± 2300.5	11,300.2 ± 2000.5	0.235
SOD activity (U/mL)	Experimental group	120.5 ± 20.3	160.4 ± 28.1	< 0.001
	Control group	118.0 ± 19.5	122.0 ± 23.1	0.135
MDA level (nmol/mL)	Experimental group	10.5 ± 2.1	7.5 ± 1.2	< 0.001
	Control group	10.8 ± 2.3	10.0 ± 2.1	0.135

5. Discussion

Painting therapy in art therapy can provide a non-verbal emotional expression pathway for individuals with autism, helping them establish connections with the outside world and promote psychological and emotional stability [13]. Biofeedback technology improves the emotional regulation ability of patients by monitoring and regulating their physiological signals in real-time [14]. However, there is still relatively little research on the impact of painting therapy combined with biofeedback technology on the neurophysiological mechanisms of autism patients, and there is a lack of systematic evaluation [15]. The study analyzed the impact of painting therapy combined with biofeedback technology on neural network signal transmission in children with autism and its potential role in improving social skills and emotional regulation by monitoring eye electrical signals, brainwave changes, and behavioral performance.

The research results exhibited that after receiving a combination of painting therapy and traditional intervention, the EG exhibited decreases in their behavioral scale scores and a significant improvement in their social adaptation scale scores. The CG only received traditional intervention, with a relatively small improvement ($p < 0.05$). In addition, during the painting therapy process, the EG showed a significant decrease in TEOAE ($p < 0.001$), indicating that their attention was more focused and their state was also more focused. The combination of painting therapy and biofeedback technology can significantly improve the neural network signal transmission of children with autism, promoting the development of their social and emotional regulation abilities. Chérel [8] suggests that painting can help individuals with autism establish connections with the world and develop unique subjective motivations. In addition, Thoen et al. [7] show that HRVB training can significantly increase cardiac vagal nerve regulation in adolescents with autism, but its long-term effects and improvement in psychosocial function still need further validation. By combining painting therapy and biofeedback technology, the study not only significantly improved the behavioral performance of children with autism in the short term but also revealed changes in their neurophysiological mechanisms through physiological monitoring data, providing a new perspective for understanding the intervention mechanisms of autism. In addition, the study also found that the EG exceeded that of the CG in indicators such as exercise ability, HRV, and resting heart rate after intervention ($p < 0.001$). This indicates that painting therapy combined with biofeedback technology can not only improve the behavioral performance of children with autism but also have a positive impact on their physiological regulation ability. This finding is matched with the research findings of Hu in reference [9], which suggests that painting therapy can promote further development of neural networks in children with autism by intervening in bioelectric signals.

In summary, the study provides a new and effective intervention for children with autism by combining painting therapy and biofeedback technology. This comprehensive intervention method not only significantly improves the behavioral performance of children with autism but also has a positive impact on their neurophysiological mechanisms. The study reveals the potential mechanism of combining painting therapy with biofeedback technology in improving the attention, emotional regulation, and social adaptation abilities of children with autism. The study has some limitations in terms of sample size and demographics. First, the sample size was relatively small, which may have limited the statistical significance and general applicability of the findings. Second, the study was focused on specific regions or groups and may not be fully representative of the wider population. Future studies should expand the sample size to improve the reliability and extrapolation of the results, while consideration should be given to including more diverse demographic samples to enhance the generality and applicability of the findings.

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Glossary

ASD	Autism Spectrum Disorder
HRVB	Heart Rate Variability Biofeedback
EEG	Electroencephalogram
HRV	Heart Rate Variability
ABC	Autism Behavior Checklist
SAC	Social Adaptation Scale
IBS/SC	Infant/Junior High School Social and Biological Competence Scale

GOALS	Goal Achievement and Learning Scale
TEOAE	Total Electrooculogram Approximate Entropy

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