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Original article

Vocal Music in Autism Therapy: Progress and Potential

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Abstract

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by challenges in social interaction, communication, and repetitive behaviors. Over time, the understanding of ASD has evolved, moving beyond early misconceptions to a more comprehensive view of its diverse symptoms and potential therapeutic strategies. Despite notable advancements, current interventions remain limited, highlighting the need for more innovative and effective approaches. This paper explores the therapeutic potential of music, with a focus on vocal music, in individuals with ASD. It examines the correlation between music therapy and improvements in emotional regulation, social skills, and communication abilities among autistic individuals. Additionally, the paper investigates the possible underlying mechanisms of vocal music therapy, including how it engages both hemispheres of the brain, enhances neuro-connectivity, and promotes the release of endorphins that contribute to emotional well-being. The potential of AI technology to personalize and optimize music therapy interventions is also explored. This review aims to synthesize the growing body of evidence supporting music, particularly vocal music, as a valuable tool in autism therapy, offering promising avenues for enhancing the quality of life for individuals on the autism spectrum.

Keywords: ***Autism, Music therapy, Vocal, Endorphins, Neuro-connectivity,***

Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by a wide range of challenges in social interaction, communication, and repetitive behaviors. It affects individuals differently and to varying degrees, often manifesting in early childhood and continuing throughout a person's life [1]. While some individuals with autism may have significant impairments in their ability to communicate and interact socially, others may possess exceptional skills in areas such as mathematics, music, or art. The increasing prevalence of autism has spurred extensive research into effective therapies and interventions aimed at improving the quality of life for those affected by the disorder [2].

Vocal music, the art of producing musical sounds with the human voice, is a form of expression that transcends cultural and linguistic boundaries. It encompasses a diverse range of styles and genres, from classical opera and choral singing to contemporary pop and jazz. Vocal music involves various techniques, including singing, humming, and vocal improvisation, which can be utilized for both artistic and therapeutic purposes. Music, as a universal language, has the profound ability to convey emotions, tell stories, and foster connections between individuals.

In recent years, there has been a growing interest in the intersection of music therapy and autism, particularly in how vocal music can serve as a therapeutic tool. Music therapy is an established clinical practice that uses music interventions to accomplish individualized goals within a therapeutic relationship. For individuals with autism, vocal music therapy can be particularly beneficial. It provides a non-verbal medium for expression, which can be crucial for those who struggle with verbal communication. Additionally, engaging in vocal music can stimulate cognitive processes, enhance social interaction, and reduce anxiety and stress. This review aims to delve into the multifaceted relationship between vocal music and autism. Key studies that demonstrate the efficacy of vocal music therapy for individuals with ASD will be discussed. Furthermore, the mechanisms through which vocal music exerts its therapeutic effects will be explored.

1. History of Autism and its Pathogenesis

1.1. History of autism

Autism, or ASD, is a developmental disability that appears early in life and significantly impacts social communication and behavior. It encompasses a range of conditions, including Autistic Disorder, Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS), and Asperger's Disorder. Individuals with ASD often face difficulties with social interactions and exhibit repetitive behaviors or restricted interests [3].

The term "autism" was first introduced by psychiatrist Eugen Bleuler in 1911 (**Figure 1**), although it referred to a subset of symptoms associated with schizophrenia [4]. It wasn't until the early 1940s that autism began to be recognized as a distinct condition. In 1943, Dr. Leo Kanner, an Austrian-American psychiatrist, published a seminal paper describing 11 children with a unique syndrome characterized by profound social withdrawal and communication difficulties, which he termed "early infantile autism" [5]. Almost simultaneously, Austrian pediatrician Dr. Hans Asperger described a milder form of autism, later known as Asperger's Syndrome,

characterized by social and communication challenges without significant language delay [5]. These foundational studies laid the groundwork for our understanding of ASD as a spectrum of related disorders.

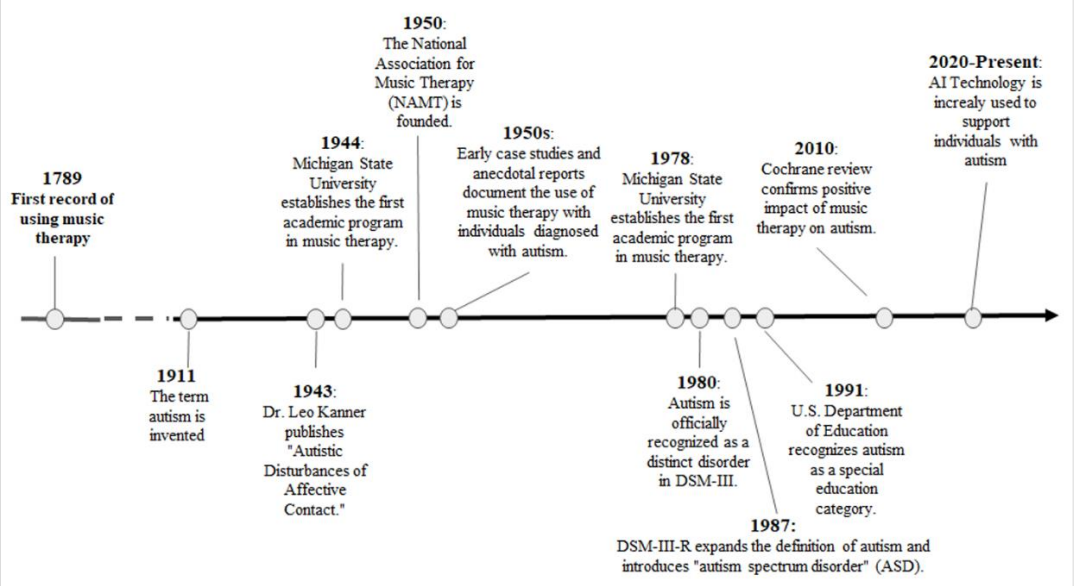

Figure 1: History of music therapy, autism and music therapy application in autism.

1.2. The potential causes of autism

The causes of autism are not fully understood, but it is generally accepted that a combination of genetic and environmental factors contribute to its development [4]. Genetic predisposition plays a significant role, with numerous studies identifying specific genes associated with the disorder, for example CHD8, SCN2A, and SHANK3 are linked to an increased risk for ASD [6]. Environmental influences, such as prenatal exposure to certain chemicals or maternal infections during pregnancy, are also believed to interact with genetic factors to increase the risk of autism. For example, maternal infections like rubella or cytomegalovirus (CMV) during pregnancy have been linked to an elevated risk of autism in the child[7].

Autism can co-occur with other medical conditions, complicating diagnosis and intervention. For instance, a study of individuals with both Down syndrome (DS) and autism revealed that autism is not uncommon in those with DS, but there is often a significant delay in diagnosis compared to children with autism alone. Factors such as a family history of autism, infantile spasms, early hypothyroidism, and brain injury after complicated heart surgery have been identified as potential contributors to the development of autism in individuals with DS. Recognizing and diagnosing autism in the presence of other conditions is crucial for ensuring appropriate support and education [8].

The understanding of autism has evolved significantly over the years, particularly with the introduction of standardized diagnostic criteria. The Diagnostic and Statistical Manual of Mental Disorders (DSM), published by the American Psychiatric Association, and the International Classification of Diseases (ICD), published by the World Health Organization, are regularly updated to reflect the latest research and clinical insights. The latest edition, DSM-5, consolidates previous subtypes of autism into a single diagnosis of emphasizing the spectrum nature of the condition [5]. This change acknowledges the wide variability in symptoms and severity, helping clinicians provide more tailored and effective interventions.

Early diagnosis and intervention are essential for effective support and education for individuals with autism. Interventions such as behavioral therapies, speech and language therapy, and occupational therapy can significantly improve outcomes, especially when initiated early in life. The increasing recognition of autism's diverse manifestations and the ongoing refinement of diagnostic criteria continue to enhance our ability to support individuals with ASD and their families.

1.3. Symptoms of Autism

ASD manifests through a variety of symptoms that can significantly impact an individual's daily life [8]. These symptoms typically fall into two main categories: challenges in social communication and interaction, and restricted, repetitive patterns of behavior, interests, or activities (**Figure 2**). Understanding the full scope of these symptoms is crucial for early diagnosis and intervention, which can greatly improve outcomes for individuals with ASD.

1.3.1. Social communication and interaction disorders

Individuals with ASD often experience difficulties with social communication and interaction. These challenges can manifest in various ways, such as struggles with reciprocal social interaction, including difficulties in engaging in typical back-and-forth conversations, understanding social cues, and forming relationships. They may also encounter language and communication barriers, such as delays or abnormalities in speech development, often speaking in single words or short phrases rather than full sentences. Additionally, nonverbal communication can be affected, with difficulties in understanding and using gestures, facial expressions, and eye contact.

1.3.2. Restricted and repetitive behaviors

Another core feature of ASD is the presence of restricted and repetitive behaviors [8]. These can include repetitive movements, such as engaging in repetitive motor movements, such as hand-flapping, rocking, or spinning; insistence on sameness, for example, having a strong preference for routines and resistance to change; and restricted interests, in case of having an intense focus on specific topics or activities, often to the exclusion of other interests.

1.3.3. Sensory issues

Individuals with ASD often also struggle with sensory issues [9]. Sensory processing abnormalities are common in individuals with ASD. These can include heightened or diminished sensitivity to sensory stimuli, such as sounds, lights, textures, or tastes. Sensory issues can contribute to difficulties in daily functioning and exacerbate other symptoms of ASD. Research suggests that these sensory abnormalities may be linked to underlying neurobiological factors, but more studies are needed to fully understand their origins and implications.

1.3.4. Gastrointestinal symptoms

Gastrointestinal symptoms (GIS) are also frequently reported in children and adolescents with ASD. These symptoms can include constipation, diarrhea, abdominal pain, and bloating. The relationship between GIS and ASD is complex and multifaceted [10]. Some studies suggest a potential link between gut health and ASD symptoms, possibly mediated by the gut-brain axis [7]. However, the findings are contradictory, and more research is required to clarify the nature of this relationship.

1.3.5. Developmental regression

Developmental regression is also common amongst individuals with ASD [8]. Developmental regression is where a child loses previously acquired skills, which can occur in some cases of ASD. This regression can be particularly distressing for families and requires targeted intervention strategies. Additionally, challenging behaviors such as aggression, self-injury, and tantrums are common and can be difficult to manage without appropriate support.

In addition, research into the neurobiological underpinnings of ASD has identified several brain regions that may be involved [11]. The medial temporal lobe and related limbic structures, including the orbital prefrontal cortex, are implicated in the social and emotional deficits observed in ASD. Neuropsychological studies have shown that children with ASD often perform worse on tasks involving these brain regions compared to children with Down syndrome or typical development.

In summary, the symptoms of ASD can change over time, with some individuals showing improvement in certain areas while others continue to struggle [8]. Longitudinal studies have found that adolescents with ASD are more likely to improve reciprocal social interaction, whereas adults may show more improvement in restricted and repetitive behaviors. However, the severity of communication difficulties tends to remain relatively stable across the lifespan.

1.4. Currently available treatments for autism

The treatment landscape for ASD is diverse and continuously evolving, incorporating various approaches to address the multifaceted nature of the condition. While no single treatment is universally effective for all individuals with ASD, a combination of interventions tailored to the individual's unique needs often yields the best outcomes. This section delves into the evidence-based treatments for ASD, their efficacy, and the areas needing further research.

1.4.1. Earlier intervention is critical for ASD treatment

Early intervention is crucial in the treatment of ASD, as it capitalizes on the brain's plasticity during the critical developmental period [10]. Studies have consistently demonstrated that early intervention programs can significantly improve developmental functioning and reduce maladaptive behaviors [12]. Key components of effective early intervention include Applied Behavior Analysis (ABA), the Early Start Denver Model (ESDM), and the Developmental, Individual Differences, Relationship-Based Model (DIR/Floortime). ABA, one of the most well-established treatments, focuses on improving specific behaviors through reinforcement strategies. The Lovaas method, a form of ABA, has shown substantial success in enhancing communication, social skills, and adaptive behaviors in young children with ASD [13]. ESDM integrates ABA principles with developmental and relationship-based approaches and has been shown to improve cognitive and language abilities in children aged 12 to 48 months [13]. DIR/Floortime emphasizes the importance of emotional and relational development by engaging children through play to build social and emotional skills [15]. Despite the documented benefits of early intervention, more randomized controlled trials are needed to identify the most effective components and understand the long-term impacts of these treatments.

1.4.2. Psychological and educational interventions

Psychological and educational interventions are essential in managing the core symptoms of ASD and improving quality of life. These interventions include social skills training, speech and language therapy, and occupational therapy (OT). Social skills training programs are designed to teach individuals with ASD how to interact appropriately with peers and adults through role-playing, social stories, and other interactive activities. Speech and language therapy helps individuals develop communication skills, whether verbal or non-verbal, working on language comprehension, speech production, and the use of communication aids when necessary [11]. Occupational therapy focuses on enhancing daily living skills and sensory integration, helping individuals with ASD manage sensory processing issues, develop fine motor skills, and improve self-care abilities.

1.4.3. Behavioral interventions

Behavioral interventions are tailored to address specific problematic behaviors associated with ASD. These may include Functional Behavior Analysis (FBA) and Positive Behavior Support (PBS). FBA identifies the causes and functions of challenging behaviors, allowing therapists to develop strategies to modify or replace them. PBS uses proactive strategies to reinforce desirable behaviors and reduce the occurrence of problematic behaviors, often involving creating supportive environments and teaching alternative skills [7].

1.4.4. Prevention and support for this no-cure and life-long condition

There is no cure for ASD, but certain medical and nutritional interventions can help manage associated symptoms. Medications are used to address comorbid conditions such as anxiety, depression, and attention-deficit/hyperactivity disorder (ADHD). Commonly prescribed medications include selective serotonin reuptake inhibitors (SSRIs) and antipsychotics. Dietary interventions, such as gluten-free or casein-free diets, may help manage gastrointestinal symptoms and improve overall well-being, although the evidence supporting these diets is mixed. Emerging research suggests that modulating gut microbiota may influence ASD symptoms [12]. While current evidence is inconclusive, ongoing studies are exploring the potential benefits of probiotics, prebiotics, and fecal microbiota transplantation.

Recent advances in neuroscience and developmental psychology have opened new avenues for the prevention of ASD [14]. Prevention strategies focus on early detection and intervention before the full syndrome manifests. These strategies include identifying infants at risk for ASD through genetic screening, neurodevelopmental assessments, and monitoring of early behavioral markers [14]. Implementing early behavioral interventions to alter the trajectory of brain development aims to mitigate risk factors and enhance protective factors to prevent the emergence of ASD symptoms.

ASD is a lifelong condition that requires ongoing support and adaptation of interventions as individuals age [14]. Key areas of focus include educational support, vocational training, and social and community integration. Tailoring educational programs to meet the needs of individuals with ASD, including specialized instruction and accommodations, is essential. Providing job training and employment opportunities helps individuals with ASD achieve independence and financial stability. Promoting social inclusion and participation in community activities enhances quality of life and reduces isolation.

The treatment of ASD is multifaceted and requires a personalized approach that considers the unique needs and strengths of each individual. Early intervention, psychological and educational support, behavioral strategies, medical and nutritional interventions, and preventive approaches all play vital roles in improving outcomes for individuals with ASD. Ongoing research and collaboration among professionals, families, and individuals

with ASD are essential to advance our understanding and develop more effective treatments.

1.5. Potential pathogenesis of ASD

1.5.1. Animal models application in ASD study

Neurodevelopmental disorders (NDDs) research, including ASD and intellectual disability (ID), reveals that these pervasive, lifelong disorders lack evidence-based interventions for core symptoms and are diagnosed primarily through behavioral criteria due to the absence of established biological markers [16]. Some behavioral neuroscience experts aimed to maximize the utility of in vivo animal models in ASD research. Key goals included identifying the limitations and potential of behavioral studies in rodent models, providing recommendations for phenotyping, and setting guidelines for reliable and rigorous use and reporting of these models. The consensus emphasized that animal models should be seen as representations of neurodevelopmental insults rather than specific disorders, stressing the need for careful validation of behavioral testing methods, data analysis, and interpretation [16].

1.5.2. Clinical investigation and outcomes

In the realm of clinical research, the modulation of excitation and inhibition (E/I) balance has gained attention. ASD, characterized by social and communication abnormalities, shows synaptic abnormalities that may be influenced by targeted interventions. An imbalance in excitatory to inhibitory neurotransmission, involving altered glutamatergic and GABAergic pathways, is implicated in ASD's pathogenesis. Clinical trials of glutamatergic and GABAergic agents have yielded promising results regarding efficacy and tolerability. However, further studies are necessary to confirm the role of E/I modulators in ASD treatment and to establish the safety and efficacy of current agents [17].

1.5.3. Ethical issues faced when studying ASD

Ethics in autism research is increasingly focused on a person-oriented approach, emphasizing respect, inclusion, and empowerment of autistic individuals. A task force of researchers, professionals, autistic self-advocates, and parents developed guidelines organized around five key principles: individualization, acknowledgment of lived experiences, empowerment in decision-making, respect for holistic personhood, and fostering researcher-participant relationships. These guidelines advocate for individualized support, accessible consent processes, and greater involvement of autistic individuals beyond their roles as research participants, highlighting the value of community engagement in ethical research practices [18].

A comprehensive review of ASD, affecting approximately 2.3% of children aged 8 years and 2.2% of adults in the US, underscores the disorder's increasing prevalence due to changes in diagnostic criteria, improved screening, and heightened public awareness. Early signs of ASD include a lack of response to name, limited use of gestures, and absence of imaginative play. Diagnosis involves a multidisciplinary evaluation using standardized measures like the Autism Diagnostic Observation Schedule (ADOS) and the Autism Diagnostic Interview (ADI), with notable sensitivity and specificity [19]. Individuals with ASD have higher rates of co-occurring conditions such as depression, anxiety, sleep difficulties, and epilepsy. Intensive behavioral interventions, particularly for children under five, show benefits in language, play, and social communication. Pharmacotherapy, including risperidone and aripiprazole, is indicated for co-occurring psychiatric conditions and can improve irritability and aggression, though these medications come with side effects such as changes in appetite, weight, and sleep[19].

1.6. Challenges for ASD study

1.6.1. The global prevalence of ASD remains uncertain

Global data on the prevalence of ASD presents numerous challenges [20]. While ASD are neurodevelopmental disorder with largely unknown etiologies, studies over recent decades have shown that it occurs worldwide, with rising recorded cases. However, accurately determining prevalence, especially in developing nations, remains a significant hurdle. Cultural norms can affect the timely and accurate diagnosis and categorization of patients, complicating data acquisition and reliability [20]. This review highlights the facts, fallacies, and limitations associated with the available global data on ASD prevalence, emphasizing the need for more robust data collection and analysis methods to obtain reliable figures. Vocal music, with its universal appeal and cultural adaptability, might bridge some of these gaps by providing a consistent and engaging medium for assessment and therapy across diverse populations.

1.6.2. Effective treatments for ASD are still limited

Current therapeutic approaches for ASD face several limitations [21]. Standard behavioral and pharmacological interventions often do not address the full spectrum of symptoms and can be limited in their effectiveness and accessibility. Behavioral therapies, while beneficial, may not fully engage children who struggle with communication and social interaction [21]. Pharmacological treatments often come with side effects and do not address core symptoms of autism, focusing instead on co-occurring conditions like anxiety or hyperactivity [22]. Additionally, the heterogeneity of ASD means that no single treatment works for all individuals, necessitating a more personalized approach [21]. Vocal music therapy presents a promising complementary solution. Music, especially vocal music, can engage multiple areas of the brain simultaneously, promoting social interaction, communication, and emotional expression. Integrating vocal music into therapeutic regimens could enhance engagement, provide an enjoyable and motivating activity, and potentially address some of the core symptoms of ASD in a holistic manner.

2. Music therapy for autism

2.1. Music therapy improving the communication ability in autistic children

Improving communication in high-functioning children with ASD remains a challenging area of study. While there has been progress in understanding the language capabilities of these individuals, knowledge about their communication at both language and non-language levels is still insufficient. Music therapy has shown significant promise in addressing these communication challenges. The therapeutic effects of music can be both calming and activating, depending on the type of music used. Given the frequent occurrence of auditory hypersensitivity in children with ASD, it is crucial to carefully select musical material and gradually introduce this type of therapy. Starting with sound habituation and passive music therapy can help acclimate children to the therapeutic process [23]. Music therapy shares similarities with other multimodal developmental support methods, incorporating elements of rhythm, movement, and sound. The flexibility of music therapy allows it to be tailored to the specific needs of each child, potentially enhancing psychomotor development and communication skills.

2.2. Music therapy improving motor and social skills in autistic children

Research on the use of technology in music therapy highlights its potential benefits for children with ASD. Autism affects social, cognitive, and motor functioning in varying degrees, and music therapy has been shown to offer cognitive, psychosocial, behavioral, and motor benefits. A systematic review of studies on music therapy and sound-based activities for autistic children identified significant improvements in motor and social skills. Technologies such as motion capture and interactive systems have been integrated into music therapy to enhance its effectiveness. These technologies make

music therapy more accessible and engaging for children with ASD, providing them with opportunities to improve their motor skills and social interactions [24]. The review also identifies commonalities, strengths, and limitations of existing research, suggesting areas for future exploration to further refine music therapy practices.

2.3. Music education for autistic children

Inclusive education has brought many music teachers into contact with children on the autism spectrum within regular classroom settings. However, traditional teaching methods relying on rote learning pose challenges for these children, who may struggle with imitation. Understanding how children with ASD respond to imitation is essential for music teachers. Research findings indicate that children with ASD often respond differently to imitation than their typically developing peers, necessitating adapted teaching strategies [25]. Music education strategies that support interventions recommended in psychological literature can be modified to better meet the needs of students with ASD. By doing so, music teachers can create a more inclusive and supportive learning environment.

2.4. Music therapy is effective and has a broad impact on autistic individuals

A comprehensive study analyzed the goals and outcomes of music therapy for individuals with ASD, ranging in age from 2 to 49 years. The study found that music therapy interventions, including interactive instrument playing, musical instrument instruction, and interactive singing, were highly effective in achieving therapeutic goals. Language and communication were the primary goal areas, followed by behavioral/psychosocial, cognitive, musical, and perceptual/motor skills. Remarkably, all participants reached their initial objectives within one year, regardless of session type, level of difficulty, or goal area. Furthermore, 77% of intermediate objectives were reached within the same timeframe. Parents and caregivers reported that skills acquired in music therapy were generalized to non-music therapy environments, indicating the broad applicability of music therapy outcomes [26].

In summary, music therapy has shown significant results in improving communication, social interaction, and motor skills in children with ASD. Its flexibility and ability to be tailored to individual needs make it a promising complementary therapy to traditional approaches. The integration of technology in music therapy further enhances its effectiveness, making it an innovative solution for addressing the limitations of standard therapeutic methods (**Figure 2**).

3. Vocal music and autism

3.1. Vocal music improves the quality of life of individuals with ASD

A growing body of literature highlights the positive impact of vocal music on individuals with ASD. Research investigating the effects of group singing on autistic adults reveals significant improvements in quality of life (QoL). A study involving eight autistic adults who participated in 12 group singing sessions demonstrated enhancements in the overarching QoL domains of Being, Belonging, and Becoming. Participants reported improved personal health, well-being, and social integration. This aligns with the philosophy of community music therapy (CoMT), which emphasizes the right of individuals to access and participate in music experiences that promote personal and communal well-being [27].

3.2. Vocal music reduces vocal stereotypy in autistic children

Studies have shown that music, particularly vocal music, can reduce vocal stereotypy in children with autism. For example, noncontingent access to music was found to decrease immediate engagement in vocal stereotypy for children with autism. Although the reduction in vocal stereotypy did not consistently carry over after the music was withdrawn, the findings indicate that music can serve as an effective tool for managing this behavior in real time [28].

3.3. Vocal music improves the overall communication skills of autistic children

Improvisational music therapy has been shown to foster vocal communication in children with ASD. A preliminary study involving video microanalysis of four children over five months revealed that vocal communication generally improved over the course of the music therapy sessions. The development was not linear, exhibiting complex patterns, but the use of 16 key vocal interventions by music therapists played a crucial role in facilitating this progress [29]. A pilot study examining the effects of vocal and instrumental improvisation in music therapy on children with autism indicated positive outcomes in various domains. Two boys diagnosed with autism showed significant improvements in verbal and nonverbal communication, behavioral patterns, cognitive skills, and social-emotional areas. The results were measured using scales such as the Child Therapist Relationship in Coactive Musical Experience Rating Form and the Musical Communicativeness Rating Form. These findings suggest that improvisational music therapy can enhance interpersonal relationships, activity engagement, and overall communicative abilities [30].

Research on noncontingent music has also examined its effects on vocal stereotypy and appropriate collateral behaviors, such as toy manipulation. One study found that noncontingent music reduced immediate engagement in vocal stereotypy for three out of four children with ASD. The intervention did not increase subsequent engagement in vocal stereotypy and had varying effects on toy manipulation. These results highlight the potential of noncontingent music as a tool to improve treatment strategies for managing vocal stereotypy in children with autism [31].

The results from these studies underscore the effectiveness of vocal music in enhancing communication, reducing stereotypic behaviors, and improving overall QoL for individuals with ASD. Vocal music therapy, particularly when involving group singing and improvisational techniques, offers a promising avenue for addressing the complex needs of this population. The flexibility and adaptability of vocal music interventions make them a valuable complement to traditional therapeutic approaches, providing autistic individuals with opportunities for personal expression, social engagement, and cognitive development.

3.4. The mechanisms through which vocal music affects autistic individuals

3.4.1. Vocal music balance endorphins in autistic individuals

It is known that endorphin levels in individuals with ASD are often either elevated or reduced compared to neurotypical individuals [32]. This dysregulation may result in sensory experiences that are either too intense or not adequately perceived, complicating the processing of environmental stimuli. Such fluctuations in endorphin levels have been linked to repetitive behaviors and challenges in sensory integration, which are hallmarks of ASD [33]. The endogenous opioid dysfunction hypothesis posits that these imbalances in endorphin levels could be due to a malfunctioning opioid system, possibly stemming from developmental anomalies during birth.

Singing, particularly in group settings such as choirs, has been shown to naturally stimulate the release of endorphins [34]. This release is associated with improved mood, reduced stress, and enhanced immune function [35]. Over time, the consistent release of endorphins through singing could contribute to stabilizing these neurotransmitter levels, offering a potential therapeutic approach for individuals with ASD.

Studies have demonstrated that singing not only triggers the release of endorphins but also modulates other neurochemicals like oxytocin and dopamine, which are critical in enhancing social bonding and emotional regulation [35]. Given that individuals with ASD often struggle with social interaction and emotional regulation, singing could provide a dual benefit: regulating neurochemical imbalances and improving social connectivity [36].

The potential benefits of singing for individuals with ASD extend beyond just the regulation of endorphin levels. Singing can serve as a multisensory activity that engages both hemispheres of the brain, fostering improved cognitive function and emotional processing [37]. It also promotes better breathing and vocal control, which can help with speech and communication skills. By stabilizing endorphin levels through regular singing, individuals with ASD may experience reduced sensory overload, fewer repetitive behaviors, and an overall improvement in mood and well-being [37].

The stabilization of endorphin levels through singing presents a promising therapeutic approach for individuals with ASD. As singing consistently releases endorphins, it may help balance the neurochemical fluctuations that contribute to the sensory and behavioral challenges associated with autism. Future research should continue to explore the long-term effects of regular singing on neurochemical regulation and its broader impact on the quality of life for those on the autism spectrum.

3.4.2. Vocal music improves neuroconnectivity in autistic individuals

Individuals with ASD are also often characterized by atypical neuroconnectivity, which is a term that refers to how different regions of the brain communicate and coordinate with each other [38]. Studies have shown both underconnectivity and overconnectivity in various brain regions in individuals with ASD, leading to a range of cognitive, social, and linguistic challenges. These neuroconnectivity patterns can manifest in difficulties with social interaction, communication, and repetitive behaviors [39].

Music, and specifically singing, has a profound impact on the brain's neuroconnectivity. It engages multiple brain regions, including those responsible for emotion, memory, and movement [40]. Research has demonstrated that music can enhance functional brain connectivity, promoting more synchronized communication between different neural networks. This synchronization is crucial in improving the overall cognitive function and social engagement in individuals with ASD.

One of the core challenges faced by individuals with ASD is impaired language development. Studies have indicated that singing can activate and strengthen the connectivity between classical language areas in the brain, such as Broca's and Wernicke's areas, as well as the cerebellum, which plays a role in the modulation of language and speech [39]. In children with ASD, particularly those with comorbid language impairments, singing has been shown to improve communication skills by enhancing these neural connections.

ASD is often associated with both overconnectivity in certain brain regions and underconnectivity between others, particularly between frontal and posterior cortical areas [41]. Singing can help compensate for these connectivity abnormalities by promoting stronger local connections and facilitating better integration of neural networks. For example, increased local connectivity in regions such as the superior parietal lobule and angular gyrus has been linked to improved cognitive function in individuals with ASD. Singing can strengthen these connections, thereby supporting better cognitive and language processing.

Beyond cognitive and linguistic improvements, singing also has emotional and social benefits for individuals with ASD. Engaging in singing can activate the brain's reward system, releasing neurotransmitters like dopamine and serotonin, which are associated with pleasure and emotional regulation [40]. This can lead to enhanced mood and reduced anxiety, which are common challenges for individuals with ASD. Additionally, singing in group settings can promote social interaction and a sense of belonging, further supporting the development of social skills.

In summary, singing can play a significant role in improving neuroconnectivity in individuals with ASD. By engaging multiple brain regions and enhancing the synchronization of neural networks, singing can help address some of the core challenges of ASD, such as language development, social interaction, and emotional regulation (**Figure 2**). Integrating singing into therapeutic interventions for individuals with ASD holds great promise for enhancing their overall QoL and cognitive functioning.

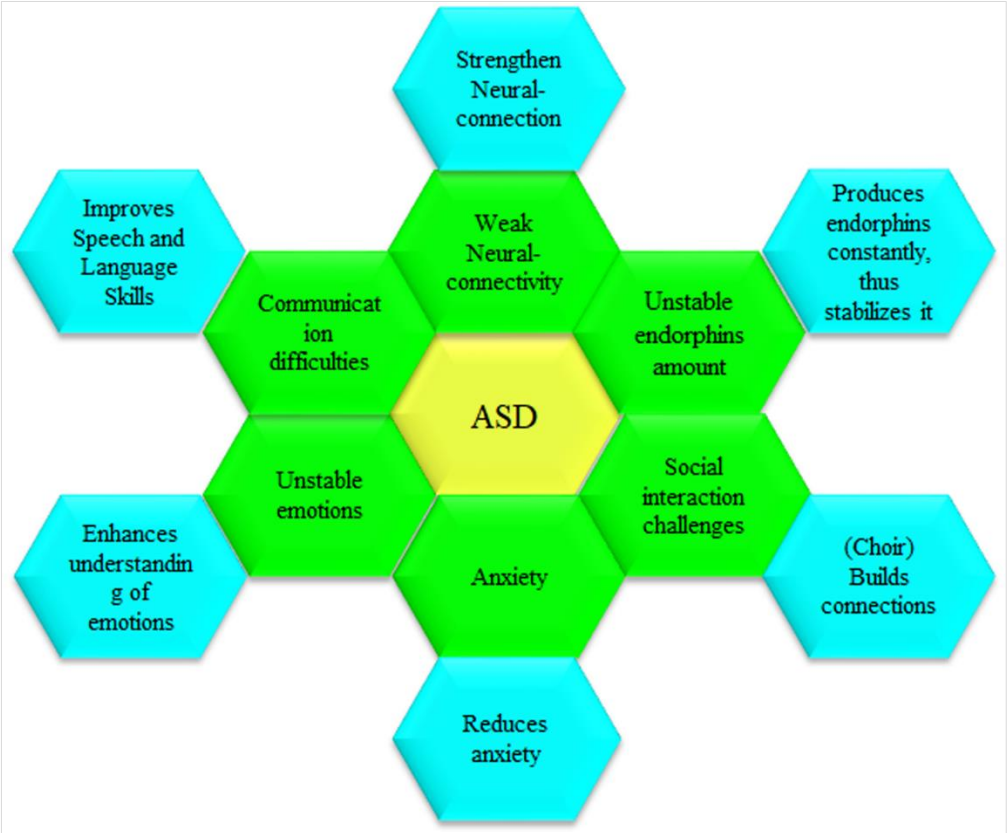

Figure 2: The mechanisms which vocal music alleviates autistic symptoms. Green blocks are the symptoms of ASD, Blue blocks are the aspects which vocal music take actions on alleviating the effects of ASD.

4. Will artificial intelligence (AI) technology be helpful?

One of the most significant challenges in autism care is the early and accurate diagnosis of ASD. Traditional diagnostic methods rely heavily on behavioral assessments, which can be subjective and vary based on the expertise of the clinician. AI has the potential to standardize and enhance the diagnostic process by analyzing large datasets to identify patterns that may not be evident through traditional methods.

4.1. AI application in ASD diagnosis

A promising approach is the use of deep learning algorithms, such as Convolutional Neural Networks (CNNs), to improve the accuracy and efficiency of ASD diagnosis. According to recent research, AI systems have been developed to replace conventional scoring functions in classic screening methods with deep learning models. These AI-based systems can analyze historical data from ASD cases, enabling them to learn and improve over time. For example, a CNN-based ASD classification system has demonstrated superior performance, with higher accuracy, sensitivity, and specificity compared to traditional methods [42]. Such advancements are particularly beneficial in clinical settings, where quick and reliable diagnoses are essential for early intervention.

Moreover, radiomic models that utilize AI are being explored to analyze brain imaging data, such as MRIs, to identify morphological features associated with ASD. These models can detect subtle differences in brain structure between ASD and non-ASD individuals, achieving remarkable accuracy rates. For instance, a newly developed AI system achieved a 98.5% accuracy rate in diagnosing autism in children aged 24 to 48 months by analyzing specialized MRIs [43]. This represents a significant leap forward in non-invasive diagnostic methods, providing a more objective and data-driven approach to autism diagnosis.

4.2. AI application in the development of personalized evaluation and treatment plan development

Beyond diagnosis, AI has the potential to play a transformative role in the therapy and education of individuals with ASD. One innovative application is the use of socially intelligent agents, such as autonomous robots, in therapeutic settings. The Aurora project, for example, explores the use of mobile robots as therapeutic tools for children with autism. These robots can interact with children in controlled environments, helping them develop social and communication skills in a non-threatening manner.

Theories of mindreading, social cognition, and imitation are central to the development of these AI-powered therapeutic tools [44]. By mimicking human-like behaviors and responding to the child's actions, these robots can provide valuable feedback and reinforcement, encouraging positive social interactions. The use of interactive environments in autism therapy also extends to virtual reality (VR) and augmented reality (AR) platforms, where children can engage in simulated social scenarios that help them practice and improve their social skills [44].

Furthermore, AI-driven applications can be used to create personalized therapy plans based on the unique needs and progress of each individual on a case-by-case basis. By continuously monitoring the child's interactions and responses, AI systems can adapt the therapy in real time, ensuring that it remains effective and engaging. This level of customization is difficult to achieve with traditional therapy methods, highlighting the potential of AI to enhance the effectiveness of autism interventions.

Despite the promising developments, several challenges remain before AI can be fully integrated into the healthcare system for autism diagnosis and treatment. One of the primary concerns is the need for extensive validation of AI models across diverse populations and settings. The accuracy and reliability of AI systems must be tested rigorously to ensure they can be trusted in real-world clinical environments. Additionally, ethical considerations, such as data privacy and the potential for bias in AI algorithms, must be addressed to prevent any unintended consequences.

Looking ahead, future research should focus on integrating AI with other emerging technologies, such as wearable devices and biosensors, to create comprehensive solutions for autism care. These technologies can provide continuous monitoring and real-time feedback, enabling more proactive and personalized interventions. Moreover, interdisciplinary collaboration between AI researchers, clinicians, and educators will be crucial for developing AI tools that are both effective and user-friendly.

5. Conclusion and perspective

The exploration of ASD reveals both the complexity of the condition and the promise of innovative therapeutic approaches. As traditional therapies have their limitations, the integration of music, particularly vocal music, emerges as a compelling avenue for enhancing the quality of life for individuals with autism. Through the stimulation of both hemispheres of the brain and the release of endorphins, vocal music therapy has the potential to improve emotional regulation, social interaction, and communication skills. The neurological and biochemical responses to music, as suggested by research, highlight the unique role that music can play in addressing the challenges associated with ASD.

Furthermore, the advancement of AI technology presents an exciting opportunity to refine and personalize music therapy for individuals with autism. By leveraging AI, it is possible to create tailored music interventions that respond dynamically to the needs of each individual, offering a level of customization and effectiveness previously unattainable. This could revolutionize the accessibility and impact of music therapy, making it a more viable option for a broader population.

In conclusion, the intersection of music, neuroscience, and technology holds significant promise for the future of autism and ways of therapy. While more research is needed to fully understand and optimize these interventions, the evidence thus far points to a powerful potential for music to bring about positive change. By continuing to explore and validate these methods, we will be able to open new pathways for supporting individuals on the autism spectrum, ultimately contributing to their emotional, social, and communicative well-being.

Looking ahead, one of the most exciting next steps for AI in autism care is to harness its power to create highly personalized therapeutic plans for individuals with ASD. AI could analyze each person's unique set of symptoms, behaviors, and responses to various interventions, allowing for tailored approaches that adapt in real time as the individual progresses. By continuously learning from each interaction, AI systems could refine their understanding of what works best for each person, optimizing therapy and improving outcomes. The goal is to move beyond one-size-fits-all solutions and develop individualized care that recognizes the diversity within the autism spectrum.

As research into the effects of music on autism continues to expand, AI could play a crucial role in uncovering the nuances of how different types of music impact individuals with ASD. Beyond the general benefits of music, we could use AI to explore how specific genres—whether classical, jazz, or rap and modes of engagement, such as singing, playing instruments, or listening, might influence neurological and emotional responses differently. This level of detail could help identify the most effective musical interventions for various subsets of the autism population, enhancing therapeutic outcomes. The integration of AI in music therapy could open new doors to understanding and leveraging the full potential of music as a powerful tool for supporting individuals with autism.

List of abbreviations

ABA: Applied Behavior Analysis
ADI: Autism Diagnostic Interview
ADHD: Anxiety, depression, and attention-deficit/hyperactivity disorder
ADOS: Autism Diagnostic Observation Schedule
AI: Artificial intelligence
AR: Augmented Reality
ASD: Autism spectrum disorder
CoMT: Community of music therapist
CNNs: Convolutional Neural Networks
DIR/Floortime: Developmental, Individual Differences, Relationship-Based Model
DS: Down Syndrome
DSM: Diagnostic and Statistical Manual of Mental Disorders
E/I: Excitation and inhibition
ESDM: Early Start Denver Model
FBA: Functional Behavior Analysis
GIS: Gastrointestinal symptoms
ICD: International Classification of Diseases
ID: Intellectual disability
NDDs: Neurodevelopmental disorders
OT: Occupational Therapy
PBS: Positive Behavior Support
PDD-NOS: Pervasive Developmental Disorder Not Otherwise Specified
QoL: Quality of life
SSRIs: Selective serotonin reuptake inhibitors
VR: Virtual Reality

Ethics approval

This does not apply as this is a literature review of already published data. We have not performed any experiments and directly collected or used any data from a patient.

Consent to participate

Does not apply as this is a literature review of already published data. We have not performed any experiments and directly collected or used any data from a patient.

Data Availability

We did not have any additional data to share. All the data is from published research and cited appropriately.

Conflicts of Interest

The authors declare no conflict of interest.

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Authors' contributions

E.P. and F.F. conceived the idea, E.P. did the literature search, E.P. and F.F. organized the data, E.P. wrote the manuscript, and E.P. and F.F. revised and final approved the manuscript.

References

[1] Understanding Autism: Exploring Diversity, Challenges, and Empowerment - Global Education News. https://eduschoolnews.com/understanding-autism/ (2024).
[2] How Many Types of Autism Are There? https://www.goldenstepsaba.com/resources/how-many-types-of-autism-are-there.
[3] Wing, L. What is autism? in Autism: Professional perspectives and practice (ed. Ellis, K.) 1-24 (Springer US, Boston, MA, 1990). doi:10.1007/978-1-4899-6924-8_1.
[4] Blake, J., Hoyme, H. E. & Crotwell, P. L. A Brief History of Autism, the Autism/Vaccine Hypothesis and a Review of the Genetic Basis of Autism Spectrum Disorders. | South Dakota Medicine | EBSCOhost. 58 https://openurl.ebsco.com/contentitem/gcd:95624069?sid=ebsco:plink:crawler&id=ebsco:gcd:95624069 (2013).
[5] MD, D. A. M. Autism History. News-Medical https://www.news-medical.net/health/Autism-History.aspx (2009).
[6] Sj, S. et al. Insights into Autism Spectrum Disorder Genomic Architecture and Biology from 71 Risk Loci. Neuron 87, (2015).
[7] Atladóttir, H. O. et al. Maternal infection requiring hospitalization during pregnancy and autism spectrum disorders. J. Autism Dev. Disord. 40, 1423-1430 (2010).
[8] Seltzer, M. M. et al. The Symptoms of Autism Spectrum Disorders in Adolescence and Adulthood. J. Autism Dev. Disord. 33, 565-581 (2003).
[9] Leader, G. et al. Gastrointestinal Symptoms in Autism Spectrum Disorder: A Systematic Review. Nutrients 14, 1471 (2022).
[10] Tan, Q. et al. Probiotics, prebiotics, synbiotics, and fecal microbiota transplantation in the treatment of behavioral symptoms of autism spectrum disorder: A systematic review. Autism Res. 14, 1820-1836 (2021).
[11] Dawson, G., Meltzoff, A. N., Osterling, J. & Rinaldi, J. Neuropsychological Correlates of Early Symptoms of Autism. Child Dev. 69, 1276-1285 (1998).
[12] Rogers, S. J. & Vismara, L. A. Evidence-Based Comprehensive Treatments for Early Autism. J. Clin. Child Adolesc. Psychol. 37, 8-38 (2008).
[13] What Is the Lovaas Method of ABA Therapy? https://www.goldstarrehab.com/parent-resources/the-lovaas-method-of-aba-therapy.
[14] Francis, K., Karantanos, G., Al-Ozairi, A. & AlKhadhari, S. Prevention in Autism Spectrum Disorder: A Lifelong Focused Approach. Brain Sci. 11, 151 (2021).
[15] What is DIR/Floortime? | TherapyWorks. https://therapyworks.com/blog/autism/dir-floortime/ (2023).
[16] Silverman, J. L. et al. Reconsidering animal models used to study autism spectrum disorder: Current state and optimizing future. Genes Brain Behav. 21, e12803 (2022).
[17] Canitano, R. & Palumbi, R. Excitation/Inhibition Modulators in Autism Spectrum Disorder: Current Clinical Research. Front. Neurosci. 15, (2021).
[18] Person-oriented ethics for autism research: Creating best practices through engagement with autism and autistic communities - M Ariel Cascio, Jonathan A Weiss, Eric Racine, and the Autism Research Ethics Task Force, and the Autism Research Ethics Task Force, 2020. https://journals.sagepub.com/doi/abs/10.1177/1362361320918763.
[19] Hirota, T. & King, B. H. Autism Spectrum Disorder: A Review. JAMA 329, 157-168 (2023).
[20] Onaolapo, O. & Onaolapo, A. Global Data on Autism Spectrum Disorders Prevalence: A Review of Facts, Fallacies and Limitations. Univers. J. Clin. Med. 5, (2018).
[21] Elbeltagi, R., Al-Beltagi, M., Saeed, N. K. & Alhawamdeh, R. Play therapy in children with autism: Its role, implications, and limitations. World J. Clin. Pediatr. 12, 1-22 (2023).

[22] Tordjman, S. et al. Animal Models Relevant to Schizophrenia and Autism: Validity and Limitations. Behav. Genet. 37, 61-78 (2007).
[23] Khyzhna, O. & Shafranska, K. Music Therapy as an Important Element in Shaping Communication Competences in Children with Autism Spectrum Disorder. J. Hist. Cult. Art Res. 9, 106-114 (2020).
[24] Ragone, G., Good, J. & Howland, K. How Technology Applied to Music-Therapy and Sound-Based Activities Addresses Motor and Social Skills in Autistic Children. Multimodal Technol. Interact. 5, 11 (2021).
[25] Scott, S. The Challenges of Imitation for Children with Autism Spectrum Disorders with Implications for General Music Education. Update Appl. Res. Music Educ. 34, 13-20 (2016).
[26] Kaplan, R. S. & Steele, A. L. An analysis of music therapy program goals and outcomes for clients with diagnoses on the autism spectrum. J. Music Ther. 42, 2-19 (2005).
[27] Young, L. Finding Our Voices, Singing Our Truths: Examining How Quality of Life Domains Manifested in a Singing Group for Autistic Adults. Voices World Forum Music Ther. 20, (2020).
[28] Lanovaz, M. J., Sladeczek, I. E. & Rapp, J. T. Effects of music on vocal stereotypy in children with autism. J. Appl. Behav. Anal. 44, 647-651 (2011).
[29] Development of vocal communication in children with autism spectrum disorder during improvisational music therapy: Nordic Journal of Music Therapy: Vol 28, No 3. https://www.tandfonline.com/doi/abs/10.1080/08098131.2018.1529698.
[30] Knapik-Szweda, S. The effectiveness and influence of Vocal and Instrumental Improvisation in Music Therapy on children diagnosed with autism. Pilot Study. J. Educ. Cult. Soc. 6, 153-166 (2015).
[31] EFFECTS OF NONCONTINGENT MUSIC ON VOCAL STEREOTYPY AND TOY MANIPULATION IN CHILDREN WITH AUTISM SPECTRUM DISORDERS - Lanovaz - 2012 - Behavioral Interventions - Wiley Online Library. https://onlinelibrary.wiley.com/doi/abs/10.1002/bin.1345.
[32] Low Plasma Immunoreactive β-Endorphin Levels in Autism. J. Am. Acad. Child Adolesc. Psychiatry 27, 430-433 (1988).
[33] Tordjman, S. et al. Pain Reactivity and Plasma β-Endorphin in Children and Adolescents with Autistic Disorder. PLOS ONE 4, e5289 (2009).
[34] Pearce, E. & Launay, J. Choir singing improves health, happiness and is the perfect icebreaker. The Conversation http://theconversation.com/choir-singing-improves-health-happiness-and-is-the-perfect-icebreaker-47619 (2015).
[35] A Review of the Physiological Effects and Mechanisms of Singing. J. Voice 32, 390-395 (2018).
[36] Nearon, K. Singing and Healing: Thought Paper. J. Nonprofit Innov. 2, (2022).
[37] Kreutz, G. et al. DOES SINGING PROVIDE HEALTH BENEFITS? (2003).
[38] Frith, C. What Do Imaging Studies Tell Us about the Neural Basis of Autism? in Autism: Neural Basis and Treatment Possibilities 149-176 (John Wiley & Sons, Ltd, 2003). doi:10.1002/0470869380.ch10.
[39] Altered functional connectivity of the language network in ASD: Role of classical language areas and cerebellum. NeuroImage Clin. 4, 374-382 (2014).
[40] Music and the Brain | Harvard Medical School. https://hms.harvard.edu/news-events/publications-archive/brain/music-brain.
[41] Human Brain Mapping | Neuroimaging Journal | Wiley Online Library. https://onlinelibrary.wiley.com/doi/abs/10.1002/hbm.22185.
[42] Shahamiri, S. R. & Thabtah, F. Autism AI: a New Autism Screening System Based on Artificial Intelligence. Cogn. Comput. 12, 766-777 (2020).
[43] New AI system achieves 98.5% accuracy in autism diagnosis. News-Medical https://www.news-medical.net/news/20231121/New-AI-system-achieves-98525-accuracy-in-autism-diagnosis.aspx (2023).
[44] Dautenhahn, K. & Werry, I. Towards interactive robots in autism therapy: Background, motivation and challenges. Pragmat. Cogn. 12, 1-35 (2004).