

A review article: Music therapy for enhancing executive functions in children with autism spectrum disorder

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ABSTRACT

Executive functions (EFs) are higher-order cognitive processes essential for learning, self-regulation, and social adaptation. Children with autism spectrum disorder (ASD) frequently exhibit EF deficits, which contribute to challenges in communication, behavior, and daily functioning. Growing attention has been directed toward alternative therapeutic approaches for enhancing EF skills, with music therapy (MT) increasingly recognized as a promising intervention. Music engages neural circuits within the frontal lobe—an area central to EF—while simultaneously providing a multisensory, motivating, and socially interactive medium for intervention. This review synthesizes current research across three key areas: (1) the association between EFs, social communication, and behavior; (2) the relationships between music, the brain, and EFs; and (3) empirical studies on MT-based EF training in children with ASD. Collectively, findings indicate that MT holds considerable potential as a complementary approach for strengthening EF skills and, in turn, improving social communication and adaptive behavior in this population.

Introduction

Autism spectrum disorder is classified in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) as a neurodevelopmental disorder defined by persistent deficits across two core domains. The first domain involves impairments in social communication and interaction, which may include limited eye contact, reduced emotional reciprocity, difficulties in forming and sustaining relationships, restricted imaginative play, and atypical use of verbal or nonverbal language in social contexts. The second domain concerns restricted and repetitive patterns of behavior, encompassing repetitive motor movements or use of objects, strong adherence to routines, highly fixated interests, and atypical responses to sensory input—such as hypersensitivity, hyposensitivity, or unusual fascination with sensory stimuli. These defining characteristics shape the clinical presentation of ASD and present substantial challenges for children's learning, social integration, and adaptive functioning.¹ Importantly, the two core domains are closely linked with deficits in executive functions (EFs). Growing evidence suggests that many of the behavioral and communicative features of ASD are not only from social or language impairments but also from underlying EF.²

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This recognition has shifted research attention toward interventions that can strengthen EF in more engaging and ecologically valid ways.³ Music has emerged as evidence that is capable of stimulating attention, emotional regulation, and cognitive flexibility through its multisensory and social nature.⁴ Consequently, understanding EFs provides a necessary foundation for exploring why music therapy may be particularly suited to enhance these higher-order cognitive processes in children.⁵

Executive functions

Executive functions—sometimes referred to as executive control or cognitive control—are higher-order cognitive processes that guide goal-directed behavior, regulate actions, and enable adaptive responses to changing demands.⁶ They are typically conceptualized as comprising three interrelated core components: cognitive flexibility,⁷ inhibition,⁸ and working memory.⁹

Cognitive flexibility refers to the capacity to shift thinking and adapt to new or unexpected situations across different contexts.¹⁰ Inhibition is the ability to suppress impulsive responses, resist distractions, and sustain attention on relevant tasks.⁸ Working memory involves the temporary storage, organization, and retrieval of information, supporting essential skills such as planning, reasoning, comprehension, and problem-solving.⁹⁻¹¹ These three core components of EFs undergo rapid development during early childhood, particularly between ages two and five, and continue to mature throughout adolescence into adulthood.¹²

Brain maturation plays a critical role in the development of EFs. Core EF skills previously mentioned, such as cognitive flexibility, inhibitory control, and working memory, are primarily supported by the prefrontal cortex (PFC). These processes also rely on interconnected neural circuits involving the cingulate cortex, parietal cortex, basal ganglia, amygdala, hippocampus, and other subcortical structures. Together, these networks enable individuals to solve complex problems, regulate behavior, and adapt to changing demands. The amygdala, situated within the limbic system, plays a crucial role in linking cognition with emotion and motivation. The rapid exchange of signals between the PFC and limbic system allows individuals to sustain interest, regulate attention, and prioritize meaningful information while filtering out less relevant stimuli.¹³ This dynamic interaction illustrates how brain maturation underpins both the cognitive and emotional dimensions of EF development.

Accordingly, understanding how music engages EF-brain systems would provide a strong foundation for investigating its therapeutic potential for ASD. The following section will therefore address: (1) the association between EFs, social communication, and behavior; (2) the relationships between music, the brain, and EFs; and (3) empirical studies on MT-based EF training in children with ASD.

Executive functions, social communication, and behavior

Executive functions are closely associated with the social communication difficulties and restricted, repetitive behavior patterns observed in children with ASD. Effective social interaction relies on several EF skills, including the ability to inhibit inappropriate responses, plan conversational turns, and flexibly shift topics.

When these skills are impaired, children often struggle to engage appropriately with others, and their everyday functioning might be disrupted.

Howard *et al.* investigated the relationship between EFs, sustained attention, language skills, and social communication in 180 children with ASD aged 2-8 years.¹⁴ The study found that children with stronger EF abilities—particularly in working memory and planning/organization—demonstrated higher levels of social communication comprehension and expression. Elevated EF skills were also linked to fewer pragmatic difficulties in communication. Furthermore, children who were able to sustain longer attention spans exhibited stronger expressive language abilities. Collectively, these findings highlight that EFs and attentional control play pivotal roles in supporting language development and social communication in children with ASD.

Executive functions also play a critical role in the language and speech development of children with ASD. In terms of receptive language, these children often demonstrate reduced vocabulary knowledge and usage compared with typically developing peers. This limitation is linked to difficulties in sustaining attention, regulating focus, and exercising self-control, all of which are necessary for consistently engaging with learning stimuli.¹⁵

Ellis *et al.* reported that school-aged children with ASD frequently display EF deficits in inhibition, cognitive flexibility, and working memory, which in turn are strongly associated with poorer language comprehension.¹⁶ Consequently, children with ASD often show lower levels of receptive vocabulary. Expressive language skills are similarly influenced by EF abilities—particularly planning, organization, lexical retrieval, and sentence formulation. Consistent with these findings, studies by McEvoy *et al.* and Gilotty *et al.* demonstrated that EF deficits negatively affect both communication and social skills.^{17,18} Specifically, children with ASD often struggle to maintain joint attention during conversations and may exhibit inappropriate initiation patterns, further complicating effective social interaction.

Restricted and repetitive behavioral patterns—such as repetitive movements, rigid adherence to routines, and highly focused interests—are strongly associated with deficits in EFs, particularly cognitive flexibility and inhibition. Iversen and Lewis conducted a meta-analysis examining the relationship between these behaviors, EF performance, and parental reports.¹⁹

Their findings indicated that higher levels of restricted and repetitive behaviors were consistently linked to greater EF deficits in flexibility, inhibition, and caregiver-reported EF skills.

Similarly, Berenguer *et al.* investigated the interplay between ASD, EFs, Theory of Mind (ToM), and behavioral problems.²⁰ ToM, defined as the ability to understand that others hold beliefs, thoughts, and perspectives different from one's own, was found to be impaired in children with both ASD and ADHD. The study showed that deficits in EF and ToM contribute jointly to difficulties in interpreting others' intentions, which in turn exacerbate behavioral problems.

While these studies show consistent links between executive function performance and social or behavioral outcomes, most of them are cross-sectional and correlational rather than experimental studies, and several rely on parent reports. These factors might make it difficult to determine whether executive function directly causes improvements in behavior or communication. Moreover, differences in age, intelligence, and co-occurring conditions such as ADHD may also influence how strongly executive function relates to social and behavioral skills.² Further longitudinal or intervention studies are needed to clarify these relationships.

In conclusion, children with ASD commonly experience deficits in EFs—particularly cognitive flexibility, inhibition, and working memory—that contribute to difficulties in social communication as well as the presence of restricted and repetitive behaviors, which lead to challenges in daily adaptability and behavioral regulation. Strengthening EF skills is therefore a critical therapeutic priority, as doing so can promote more effective communication, support social integration, and encourage adaptive behavioral patterns.

Music, brain, and executive functions

A variety of interventions are available to support development in children with ASD, including speech therapy, occupational therapy, and applied behavior analysis, each of which should be tailored to the individual child's needs and characteristics.³ Among these, music therapy (MT) has received increasing attention as a complementary approach.²¹ Emerging evidence suggests that MT is effective in fostering language, social, and behavioral development,²² as well as engaging both cognitive and emotional systems, which may offer a promising pathway for enhancing EFs in children with ASD.²³⁻²⁴

Early childhood is often described as a golden period of intellectual, emotional, and behavioral growth. During this stage, the brain is highly flexible and particularly sensitive to environmental stimuli.²⁵ Rapid synaptic formation occurs as children engage

with experiences and external inputs, shaping neural architecture and cognitive development. Among the most powerful of these stimuli is music, a complex multisensory experience that promotes integrated brain learning. Music engages both hemispheres of the brain simultaneously, activating networks involved in auditory processing, movement, language, and emotion.⁴ When children are exposed to music—whether through listening, singing, or movement—the brain coordinates these functions in parallel, strengthening connections between neural pathways. This integrated stimulation supports the development of essential cognitive and behavioral skills, including attention, short-term memory, self-control, and social interaction.²⁶

Beyond its immediate effects, music training and regular music exposure can lead to lasting structural and functional changes in the brain. These neuroplastic adaptations are particularly evident in regions associated with movement and auditory processing, where music training has been shown to increase cortical representation. Such training also enhances a range of cognitive skills, including verbal memory, phonological awareness, and spatial reasoning. Moreover, research indicates that attentive listening to music can induce changes in the auditory cortex, supporting the view that music exposure may positively influence executive functioning by strengthening neural networks involved in attention, memory, and cognitive control.²⁷⁻²⁸

Music therapy is a structured therapeutic process in which trained therapists use musical experiences—and the therapeutic relationship itself—to promote health and facilitate change according to individualized goals.²⁹ The American Music Therapy Association (AMTA) defines MT as an intervention designed to meet physical, emotional, cognitive, and social needs through musical activities such as composing, singing, moving, and listening.³⁰ Evidence from a systematic review by Rodriguez-Gomez and Talero-Gutiérrez⁵ indicates that MT can stimulate activity in the frontal lobe, the brain region central to EFs. Such stimulation has been shown to significantly support the development of cognitive flexibility, inhibitory control, and working memory in children.

In conclusion, music therapy is more than an enjoyable activity; it is a powerful therapeutic tool for strengthening EFs, particularly in children who require support for learning and behavior. By integrating structured musical experiences into developmental programs, MT can promote cognitive flexibility, inhibitory control, and working memory while also fostering social and emotional growth. Consequently, incorporating music as a sustained component of child development initiatives should be actively encouraged and further expanded in both clinical and educational settings.

Music therapy effects on executive functions in children with ASD

A growing body of research, conducted both internationally and in Thailand, demonstrates that music therapy interventions targeting EFs can significantly enhance EF skills in children with ASD.²³⁻²⁴ Recent publications reinforce MT as a promising intervention for cognitive development, providing empirical support for its effectiveness across diverse cultural and clinical contexts.

For example, Sharma and Mehta²³ conducted a study in India examining the effects of music therapy (MT) on executive functions in 100 children with ASD. Participants in the experimental group attended MT sessions twice weekly for 40 minutes over eight weeks, while the control group received no intervention. The sessions incorporated rhythm- and melody/swar-based activities, with both children and caregivers engaging in interactive exercises. Tasks included passing small cushions and large pillows in time with musical rhythms to encourage attention and coordination, singing familiar songs such as Chanda Mama Door Ke, Chiriyani Di Chaal, and Jingle Bells, and participating in movement-based games (e.g., “sing and stop,” “clap and go,” “clap and jump”).

Results showed that children in the experimental group demonstrated significant improvements in EF performance, as indicated by reduced post-intervention dysfunction scores. However, the study had several limitations: it did not account for children’s baseline interest in music, the short intervention period may have limited the effect size, and individual rather than group therapy was used due to variability in hyperactivity and sensory sensitivities among participants.²³

Rupsuwan *et al.* conducted a single-case study in Thailand to examine the effects of a virtual music therapy (MT) model on executive functions in a five-year-old boy with ASD.²⁴ The child and his mother participated in eight sessions delivered twice weekly for 30-45 minutes for four weeks. Sessions were conducted via telehealth, with the therapist using a laptop equipped with a camera and condenser microphone, while the mother joined through a smartphone.

The intervention targeted EF skills by combining intellectual and emotional engagement through music listening, structured musical activities, and behavioral reinforcement strategies. Activities included instrument play, singing, movement, and musical games. The therapist provided live music by singing and playing the guitar, adjusting rhythm, tempo, and dynamics to match the child’s progress. Favorite songs were incorporated to enhance motivation, and the child was encouraged to choose instruments and participate actively. Both live and recorded music supported movement-based activities, with lyrics, rhythm, and tempo providing cues for attention, initiation, and stop-go responses.²⁴

Results showed improvements in EF performance, including working memory, inhibitory control, and

cognitive flexibility, as well as reductions in behavioral problems. However, the results of this study were limited by its single-subject design without a control group, short intervention period, and the inherent limitations of virtual delivery (e.g., reduced nonverbal interaction, internet instability, and limited camera angles, which could restrict the generalizability of the results.²⁴

Rupsuwan *et al.*²⁴ highlighted the multifaceted impact of virtual music therapy (MT) on executive functions (EFs).²⁴ First, working memory improved through repetitive melodies and lyrics that supported song recall, particularly when paired with role modeling and therapist guidance. Second, inhibitory control was strengthened via musical play and movement activities that incorporated role switching and rhythmic start-stop patterns, thereby enhancing sustained attention. Third, cognitive flexibility was fostered through varied musical elements—such as changes in rhythm, tempo, lyrics, and volume—that encouraged adaptation to auditory shifts and behavioral adjustment in social contexts. Fourth, emotional regulation benefited, as music and movement provided calming effects, facilitated emotional expression, and supported the management of negative emotions. Finally, planning and organization were promoted through composing and engaging in songs tied to daily routines and target behaviors, helping the child sequence tasks and structure actions effectively.

Despite these positive outcomes, the study faced several limitations. Its single-subject design without a control group restricts generalizability, while the short intervention period precludes long-term follow-up. Additionally, constraints of virtual delivery—including reduced nonverbal interaction, restricted camera angles, and internet instability—introduced time lags and limited engagement.²⁴

Consistent with the findings of Srinivasan and Bhat,³¹ rhythm and melody stimulate reward- and emotion-related brain circuits. Regular participation in rhythm-based activities helps children regulate arousal, reduce anxiety, and sustain attention—effects that are particularly valuable during therapeutic or educational sessions. Activities such as clapping to rhythm, playing percussion instruments, or moving in response to melodic cues also support gross and fine motor coordination, thereby strengthening timing, sequencing, and inhibitory control—core aspects of executive function frequently impaired in ASD.

Similarly, Sutikno *et al.* demonstrated that singing activities in preschool children enhance memory, increase learning motivation, and foster creativity.³² Participation in singing activates neural processes that facilitate the absorption and retention of information. Moreover, the repetitive use of words in theme songs reinforces recall, enabling children to remember and integrate material more effectively.

Although existing studies indicate that MT can enhance several aspects of executive functioning in ASD, current evidence on music therapy targeting executive functions in autistic children remains limited, with few studies explicitly evaluating EF outcomes and mostly relying on small or single-case samples. The group-based interventions²³ demonstrated general feasibility, whereas individualized, virtual approaches²⁴ provided insight into mechanisms such as rhythm-based attention and emotional engagement. Active, participatory forms of music therapy, particularly incorporating rhythm, singing, and movement, appear most effective for improving inhibitory control and working memory, while effects on planning and cognitive flexibility are less consistent.

Taken together, these studies demonstrate that music therapy, whether delivered in person to large groups or virtually in single-case formats, consistently benefits the development of EFs in children with ASD. Repetitive, rhythm- and melody-based activities, along with active caregiver participation, appear to be key mechanisms underlying improvement. However, methodological differences emphasize the need for future research to balance the scalability of group interventions with the individualized, domain-specific insights afforded by case studies.

Practical implications

This study highlights several important implications for practice and research. Rhythm- and melody-based activities can be embedded into interventions to strengthen working memory, attention, inhibition, and cognitive flexibility. Simple strategies such as repetitive songs and musical games serve as effective tools for reinforcing EF skills both in therapy and in daily routines. Caregiver involvement enhances engagement and promotes generalization, while parent training extends benefits into the home environment.

The Indian study demonstrated the feasibility of structured, group-based MT, whereas the Thai case illustrated the potential of telehealth delivery, suggesting that MT can be adapted to diverse contexts, including resource-limited settings. Incorporating children's preferred music increases motivation, while rhythmic cues help regulate behavior and reduce repetitive patterns. Collectively, these findings position MT as a practical, child-friendly intervention for improving cognitive and behavioral outcomes. Nonetheless, further research is needed to evaluate longer intervention periods, develop standardized protocols, design scalable models, and determine how factors, such as age, baseline cognitive ability, and sensory sensitivities, e.g., auditory hypersensitivity commonly found in ASD, influence responsiveness and comfort for broader implementation of the intervention.

Conclusion

Children with ASD commonly experience deficits

in EFs-particularly cognitive flexibility, inhibition, and working memory-that adversely affect social communication and behavior. Music therapy has emerged as a promising and engaging intervention that stimulates brain regions involved in EF, most notably the prefrontal cortex. Interestingly, it integrates cognitive, motor, and emotional engagement within a single activity, activating multisensory and brain systems that support EF. Evidence from studies conducted across different countries demonstrates that MT, whether delivered in person or virtually, can significantly enhance EF skills in children with ASD. Reported benefits include improvements in working memory, inhibitory control, emotional regulation, and behavioral planning. Additionally, structured and individualized MT interventions have been shown to reduce repetitive behaviors and foster broader social and communicative development. Collectively, these findings underscore the therapeutic value of integrating music-based EF training into intervention programs for children with ASD. By strengthening cognitive and behavioral capacities through enjoyable, child-centered activities, MT represents a practical and adaptable approach to supporting development across diverse contexts.

Ethical approval

This is a review article, which did not directly involve human subjects. Therefore, ethical approval was not required for this paper.

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Conflict of interest

The authors declare no conflict of interest.

CRedit authorship contribution statement

Natwipa Wanicharoen: conceptualization, investigation, project administration, supervisor, writing original draft, review and edit; **Thanasak Kalaysak:** writing original draft, review and edit, correspondence; **Supaporn Chinchai, Kitisupornphan and Vich Boonrod:** writing review and edit.

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