

Research Article

Music-Based Activities and Neurodevelopment in Early Childhood: A Narrative Review

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ABSTRACT

Early childhood is a period of rapid brain growth and heightened experience-dependent plasticity, when everyday experiences help shape cognitive, language, motor, and socio-emotional development. Music-based activities such as singing, rhythmic movement, clapping, instrumental play, listening, and musical games combine auditory, motor, memory, attentional, and social demands within a single enjoyable experience. This narrative review examines evidence on the role of music-based activities in early childhood neurodevelopment, with emphasis on executive, language, motor, and socio-emotional domains, and outlines possible neurobiological mechanisms. Systematic reviews, meta-analyses, and key experimental and observational studies published between 2001 and 2025 were considered, covering formal music training, rhythm-based activities, singing, and natural caregiver-child musical interaction. Recent meta-analyses report small-to-moderate improvements in executive functions after music training, with the most consistent gains in inhibitory control, followed by working memory and cognitive flexibility. Smaller positive effects have been reported for auditory and linguistic processing and for phonological awareness, while evidence for motor, IQ, and general cognitive outcomes is less consistent and depends on the outcome measure used. Much of the evidence comes from heterogeneous, often non-randomized studies, and associations between music and development are open to confounding. Music-based activities therefore appear to be a promising, low-cost, and accessible enrichment strategy for early childhood, including simple everyday practices at home, in preschools, and in anganwadi settings, rather than a stand-alone intervention. Well-designed randomized trials in young children, including in low- and middle-income settings, are needed.

Keywords: Early Childhood, Neurodevelopment, Music-Based Activities, Music Training, Executive Function, Rhythm.

INTRODUCTION

Early childhood is a period in which children build cognitive, language, emotional, social, and motor abilities through everyday activities such as play, conversation, storytelling, singing, rhymes, drawing, dancing, and games. Brain development begins before birth and continues into early adulthood, but many of its foundations are laid in the first years of life. During this period, both brain volume and cognitive capacity increase markedly, and the infant's interaction with the environment helps shape connections within and between cortical regions [1]. By about six years of age, total brain size reaches roughly 90% of adult size, although grey and white matter continue to change through childhood and adolescence [2]. In the first few years of life, more than one million new neural connections are estimated to form every second. This phase of rapid growth is followed by pruning, in which frequently used connections are strengthened and less-used

ones are removed, making brain circuits more efficient [3].

Neuroplasticity refers to the capacity of the nervous system to change its structure and function in response to experience. Learning can alter synaptic connections, grey and white matter structure, and the organization of neural networks [4]. Musical training is a well-studied model of experience-dependent plasticity because it draws on auditory perception, attention, movement, timing, memory, and continuous sensory feedback at the same time. Behavioural, functional, and structural brain changes have all been linked to it [5]. Playing, reading, and listening to music each require several brain regions to work together in an ordered sequence, and plasticity is involved in all of these functions [6].

Music also has a place in children's emotional and social lives. It offers a channel for self-expression and a way of communicating with

others, and it can present young children with multisensory challenges that support learning [7,8]. Many musical tasks call on executive functions, a set of higher-order skills that includes planning, working memory, inhibitory control, and cognitive flexibility [8]. Neurobiological and animal studies have also been used to explore the mechanisms through which music might influence cognitive performance [9].

Despite growing interest, evidence on music and child development is spread across different age groups, activity types, and outcome measures. This narrative review therefore examines the role of music-based activities in early childhood neurodevelopment, with particular attention to executive, language, motor, and socio-emotional domains, and outlines the neurobiological mechanisms that may underlie these effects. It also considers practical implications for parents and early childhood educators.

SCOPE AND APPROACH

This is a narrative review. It draws on systematic reviews, meta-analyses, and selected experimental and observational studies published between 2001 and 2025 on music-based activities and neurodevelopment in children. Priority was given to recent meta-analyses and to studies involving children up to six years of age. Studies in older children and adults were included where they helped explain underlying mechanisms. Evidence on formal music training, rhythm-based activities, singing, and natural caregiver-child musical interaction was considered. No formal quality appraisal or quantitative synthesis was undertaken.

Relevant literature was identified through PubMed and Google Scholar, supplemented by the reference lists of key reviews. Searches covered English-language publications up to October 2026 and combined terms for music ("music training", "music intervention", "music education", "singing", "rhythm") with terms for development ("neurodevelopment", "executive function", "inhibitory control", "language", "phonological awareness", "motor", "neuroplasticity") and age ("infant", "preschool", "early childhood"). Studies were selected for relevance by the authors rather than through predefined eligibility criteria.

MUSIC-BASED ACTIVITIES IN EARLY CHILDHOOD

Music-based activities in early childhood cover a wide range of experiences. They can be planned or spontaneous, carried out alone or in a group, and can involve active participation or listening. Common examples include singing songs and rhymes, caregiver-child singing, clapping and tapping to a beat, dancing and rhythmic movement, musical storytelling, imitating sounds and rhythms, simple percussion activities, playing age-appropriate instruments, listening and responding to different sounds, stop-and-go musical games, moving to changes in tempo, and group singing and musical play.

This broad definition matters because developmental benefits should not be limited to formal instrumental instruction. For young children, the value of music may come from the combination of sound, rhythm, movement, repetition, attention, memory, and social interaction. An activity may be simple while its developmental demands are complex. When a child hears a familiar rhyme and claps at the right moment, the child is processing auditory information, recalling a learned pattern, anticipating the next beat, coordinating hand movements, and maintaining attention, all at once.

Different kinds of musical activity offer different opportunities. Singing and rhythmic rhymes support listening, language, and verbal expression. Activities that combine rhythm and movement engage attention, coordination, and body awareness. Group musical activities encourage participation, turn-taking, cooperation, and emotional expression. Music can also make learning more enjoyable and give children ways of expressing themselves that conventional classroom tasks may not offer.

NEUROBIOLOGICAL BASIS OF MUSIC AND NEURODEVELOPMENT

Figure 1 summarizes the conceptual framework of this review. Music-based activities engage auditory and rhythm processing, which in turn place shared demands on attention, memory, timing, and response control. These demands overlap with the skills that underpin executive, language, motor, and socio-emotional development. Experience-dependent neuroplasticity is proposed as a possible underlying mechanism linking repeated musical engagement to these outcomes. The pathway is a framework for interpreting the evidence, not a tested causal model.

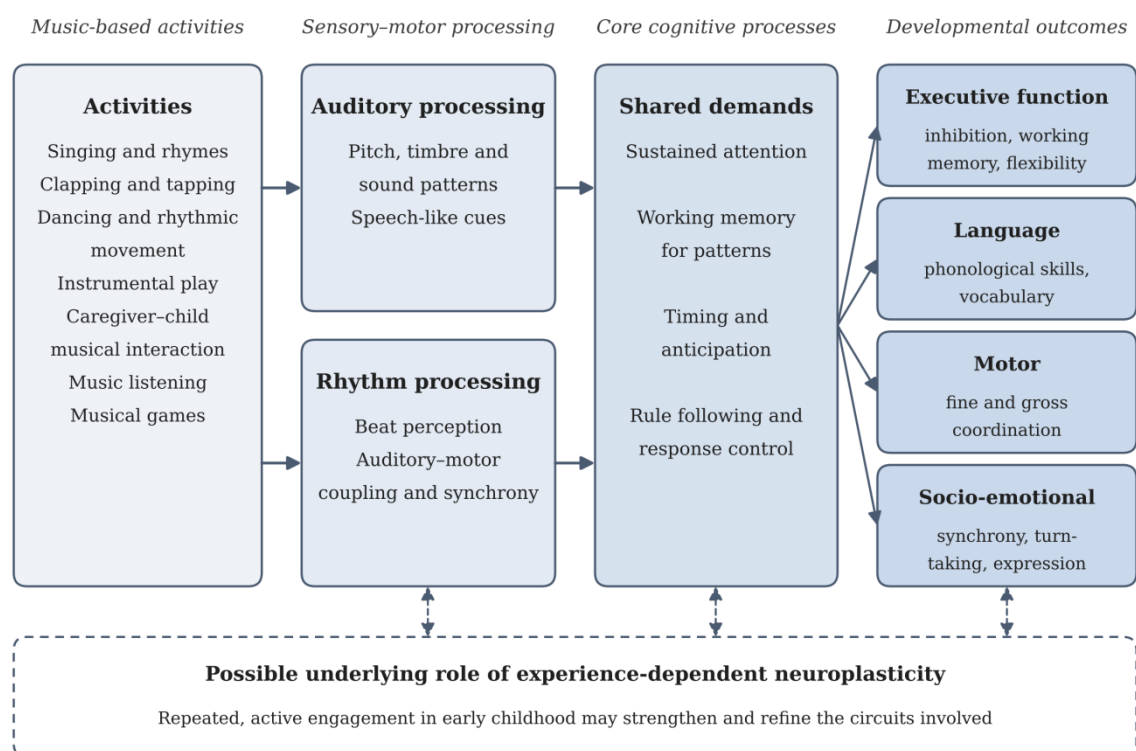


Figure 1. Conceptual framework linking music-based activities to early childhood neurodevelopment. Solid arrows show the proposed sequence from activity to sensory-motor processing, shared cognitive demands, and developmental outcomes. The dashed band indicates the possible, not yet established, role of experience-dependent neuroplasticity. Original figure prepared by the authors.

Music as A Multisensory Experience

Music is a rich multisensory experience. Listening provides auditory information, while singing and playing an instrument also engage sensorimotor regions. Playing an instrument adds a further layer, as sensory information must be integrated with motor output under continuous auditory feedback. For this reason, musical learning is regarded as a useful model for studying experience-dependent brain plasticity [5]. Wang and Agius similarly describe playing, reading, and listening to music as complex processes that require coordinated activity across multiple brain regions, with plasticity involved throughout [6].

Music Listening and Neuroplasticity

Music is a complex stimulus that engages multiple brain regions and circuits. Perception begins when sound waves are converted into neural signals in the cochlea. These signals are progressively transformed in the auditory brainstem before reaching cortical areas, where features such as pitch, timbre, rhythm, and musical structure are analysed [10]. Musical experience can shape this pathway at several levels, from early auditory encoding to higher-order executive processes. This may help

explain how musical training could transfer to broader cognitive skills [11].

Music listening also engages emotion and reward systems. Blood and Zatorre used positron emission tomography to measure regional cerebral blood flow in adult participants while they listened to self-selected music that reliably produced intense pleasure, or "chills" [12]. As the intensity of chills increased, blood flow changed in regions linked to reward, motivation, emotion, and arousal, including the ventral striatum, midbrain, amygdala, orbitofrontal cortex, and ventromedial prefrontal cortex. These regions also respond to other strongly rewarding stimuli such as food. Although the study involved adults, it offers one explanation for why music is intrinsically motivating, a feature that may help sustain young children's engagement in music-based learning.

Neuroplasticity and Sensitive Periods

Because the young brain adapts continuously to its environment, early experience may carry particular weight [1]. Research on musical training suggests that the age at which training begins can matter. Steele et al. compared adult musicians who began training before the age of

seven with those who began later but had a similar total amount of training [13]. Early-trained musicians showed greater white-matter integrity in the posterior midbody of the corpus callosum, a region connecting motor areas of the two hemispheres, and performed better on a sensorimotor synchronisation task. These findings support a sensitive period for some effects of musical training, although they come from retrospective comparisons in adults rather than from studies that followed children over time.

MUSIC-BASED ACTIVITIES AND COGNITIVE DEVELOPMENT

Cognitive development spans attention, memory, processing speed, reasoning, and problem-solving. Musical activities exercise many of these skills. Learning a song requires attention and memory. Tapping in time to a beat requires sustained attention and motor coordination. A musical game requires the child to remember instructions and hold back impulsive responses.

In an early study, Forgeard et al. compared children who had received at least three years of instrumental training (mean 4.6 years) with children who had not [14]. The trained group performed better on two outcomes closely related to music, auditory discrimination and fine motor skill, and on two more distant outcomes, vocabulary and nonverbal reasoning. Longer training predicted better performance on these measures, but no advantage was found for spatial skills, phonemic awareness, or mathematics. Because the design was correlational, the findings do not show that training caused the differences.

More recent work has drawn on systematic reviews and meta-analyses of randomised trials. Jiang et al. pooled seven randomised controlled trials involving 337 children, four in infants and three in preschool children [15]. No significant cognitive benefit was found on the Bayley Scales of Infant and Toddler Development, but positive effects were reported for language, motor skills, and IQ when other instruments were used. The results point to possible developmental benefits while showing how strongly conclusions depend on the choice of outcome measure and study design.

MUSIC AND EXECUTIVE FUNCTIONS

Executive functions are especially important in early childhood because they support a child's ability to regulate behaviour, sustain attention,

hold information in mind, shift between tasks, and control impulses. Their three core components are inhibitory control, working memory, and cognitive flexibility, and music-based activities can engage all three. A stop-and-go musical game requires a child to stop moving when the music stops, which draws on inhibitory control. Repeating a rhythm requires holding it in mind, which draws on working memory. Changing movements when the tempo or instruction changes requires cognitive flexibility.

Lu et al. pooled ten studies of preschool children aged 3–6 years [16]. Compared with controls, children who received music training showed significant improvements in inhibitory control (standardised mean difference [SMD] 0.38), working memory (SMD 0.35), and cognitive flexibility (SMD 0.23). Subgroup analyses suggested that gains in cognitive flexibility were associated with programmes lasting at least 12 weeks, delivered at least three times a week, with sessions longer than 40 minutes.

Jamey et al. reviewed 22 longitudinal studies, eight of them randomised controlled trials, and found that music training improved inhibitory control in children compared with control programmes, although study designs and populations varied [17]. The largest synthesis to date, a three-level meta-analysis by Cai et al., included 46 studies with 3,530 children aged 3–12 years and 192 effect sizes [18]. Musical training had an overall small-to-moderate positive effect on executive function (Hedges' $g = 0.35$). The effect was largest for inhibitory control ($g = 0.47$), followed by working memory ($g = 0.30$) and cognitive flexibility ($g = 0.20$), and it grew with longer training duration.

Taken together, these findings suggest that music offers a meaningful setting in which young children can practise executive skills. The benefit is likely to come less from passive listening than from active engagement with rhythm, rules, sequencing, movement, and musical decision-making.

MUSIC, AUDITORY PROCESSING, AND LANGUAGE DEVELOPMENT

Music and language share several features, including timing, rhythm, intonation, sequencing, and attention to sound patterns. Language development itself depends on auditory discrimination, phonological processing, vocabulary, comprehension, and expressive communication. These overlaps

have led researchers to propose that musical experience may support language development. The link may matter most in the first years of life, when children are acquiring listening skills, vocabulary, phonological awareness, and early communication.

Songs and rhymes are especially relevant because they pair repetitive language with rhythm and melody. Repetition helps children become familiar with sounds and words, while rhythmic structure may draw attention to the timing of speech.

Neves et al. analysed 62 longitudinal studies with 3,928 participants and found a small positive effect of music training on both auditory and linguistic processing. A narrative synthesis of brain measures in the same review also reported benefits for auditory, speech, and prosody processing [19]. The authors cautioned that further studies are needed to rule out publication bias. An earlier meta-analysis by Gordon et al. found a small positive effect of music training on phonological awareness but no consistent effect on reading fluency [20].

These findings suggest that music may complement, but not replace, language-rich interaction. Singing, rhyming, storytelling, conversation, and shared reading are best viewed as connected experiences rather than separate interventions.

MUSIC, MOTOR DEVELOPMENT, AND COORDINATION

Motor development in early childhood includes gross motor abilities such as running, jumping, balancing, and coordinated body movement, and fine motor abilities such as grasping, manipulating objects, and coordinated hand movements. Music-based movement activities offer an enjoyable setting in which to practise these skills. Dancing, rhythmic walking, clapping, tapping, and playing simple percussion instruments all require children to coordinate movement with auditory cues.

Fine motor advantages were among the outcomes associated with instrumental training in the study by Forgeard et al. [14]. The meta-analysis by Jiang et al. also reported positive effects of music intervention on motor outcomes when these were assessed with certain developmental scales [15].

Rhythm deserves particular attention. It provides an external timing structure around

which movement can be organised. A child who claps along with a beat is learning to synchronise movement with sound. Over time, such activities may strengthen the link between auditory perception and motor planning.

MUSIC, EMOTIONAL DEVELOPMENT, AND SELF-REGULATION

Early childhood is also a period in which children gradually learn to recognise, express, and regulate emotions. Music can provide a structured and emotionally engaging setting in which to practise these abilities. A lullaby can help build a predictable calming routine. An energetic song can encourage movement and positive emotional expression. Group singing creates shared attention and participation, and musical games offer practice in waiting, turn-taking, and following rules.

The caregiver–child relationship is central here. In a systematic review of natural musical interactions between caregivers and children under three years of age, Caverio et al. found that the most commonly studied interaction was mothers singing to typically developing infants under 12 months [21]. The variables most often analysed were infant attention, parental vocal behaviour, and synchrony between caregiver and infant. The prominence of synchrony in this literature suggests that coordinated musical interaction is relevant to understanding early social development.

The developmental value of music may therefore extend beyond individual cognitive skills. Music can create a shared social space in which children experience attention, imitation, emotional expression, turn-taking, and connection.

SUMMARY OF EVIDENCE BY ACTIVITY TYPE

Table 1 compares the main types of music-based activity, the developmental domains they are most likely to engage, the key findings, and the consistency of the evidence reviewed here. Evidence is strongest for structured music programmes and executive functions, where three meta-analyses agree [16–18]. Evidence for singing and listening on their own is more limited, and evidence on caregiver–child musical interaction is still largely descriptive. Most meta-analyses pooled programmes that mixed several activity types, so effects cannot always be attributed to a single activity.

Table 1. Summary of evidence for major music-based activities in early childhood

Activity type	Main developmental domains	Key findings	Consistency and strength of evidence	Refs.
Singing and rhymes	Language, phonological awareness, auditory attention, memory	Music training produced small positive effects on auditory and linguistic processing (62 studies) and on phonological awareness, but not consistently on reading fluency.	Limited to moderate. Effects are small and come mostly from mixed music programmes rather than singing alone.	[19,20]
Rhythmic movement	Executive function, motor coordination, timing	Music training programmes, many including rhythm and movement, improved inhibitory control, working memory, and cognitive flexibility in preschool children. Movement-based training showed a small effect on executive function. Motor gains appeared on some scales but not others.	Moderate for executive function, with consistent gains in inhibitory control. Limited for motor outcomes.	[15,16,18]
Instrumental play and training	Executive function, auditory discrimination, fine motor skills, vocabulary, nonverbal reasoning	Training improved inhibitory control. Longer instrumental practice was associated with better auditory, motor, verbal, and reasoning scores. Early training was linked to differences in brain structure in adults.	Moderate for executive function; limited for broader cognition. Much of the evidence is observational or from adults, and effects shrink in better-controlled studies.	[13,14,17,22]
Caregiver–child musical interaction	Attention, interpersonal synchrony, emotional regulation, early communication	Studies focus mainly on mothers singing to infants under 12 months. Infant attention, parental vocal behaviour, and dyadic synchrony are the most studied variables.	Emerging. Largely descriptive and observational, with few developmental outcome data.	[21]
Music listening	Emotion, reward and motivation, auditory perception	Highly pleasurable music activated reward and emotion regions in adults. Music perception engages a staged pathway from brainstem to cortex.	Weak for developmental outcomes. Evidence is mechanistic and mostly from adults, with no demonstrated transfer to executive or language skills in young children.	[10,12]

Ratings reflect the authors' qualitative judgement of the studies cited in this review. They are not derived from a formal grading system such as GRADE.

EVERYDAY MUSIC AS A DEVELOPMENTAL EXPERIENCE

A practical implication of this evidence is that developmental music experiences do not require expensive instruments, specialised classrooms, or professional musicians. A caregiver singing while feeding a baby, a parent clapping during a rhyme, a child dancing to music, or a teacher using a rhythmic song to introduce a lesson can all provide meaningful stimulation. As Table 1 shows, these everyday activities draw on several developmental domains at once. This makes music especially suitable for early childhood settings, because it can be built into ordinary routines rather than treated only as a separate subject

DEVELOPMENTALLY APPROPRIATE MUSIC ACTIVITIES

Music-based activities can be adapted to a child's developmental stage (Table 2). Up to about two years of age, the emphasis should be on interaction, sensory engagement, repetition, and emotional connection rather than formal instruction. At three to four years, short rule-based games and rhythm activities can be introduced. At five to six years, activities can become more structured and cooperative, with multi-step instructions and simple instruments. Activities that call on attention, inhibition, working memory, and cognitive flexibility for children aged 3–6 years are consistent with recent evidence on executive functions in preschool children [16]. The suggestions in Table 2 are practical examples drawn from this review, not tested age-specific protocols.

Table 2. Suggested music-based activities by age group

Age group	Suitable music-based activities	Developmental domains potentially supported
0–2 years	Caregiver singing and lullabies, rocking or bouncing to music, simple action songs, imitating vocal sounds, clapping games, naming sounds	Attention, early communication, imitation, emotional connection
3–4 years	Action songs and rhymes, stop-and-go games, moving to changes in tempo, copying short rhythms, simple percussion, musical storytelling	Inhibitory control, working memory, vocabulary, gross motor coordination
5–6 years	Group singing, following two- or three-step musical instructions, memory-based musical games, longer rhythm patterns with variations, simple instruments	Cognitive flexibility, phonological awareness, fine motor skills, cooperation

DISCUSSION

The available literature gives an encouraging picture of the relationship between music and early childhood neurodevelopment. The strength of music as a developmental activity may lie in its ability to engage several systems at once. Unlike an activity designed to train a single skill, music can combine auditory processing, movement, memory, attention, language, emotion, and social interaction within the same experience. This multisensory character offers a plausible explanation for why music has been studied across so many developmental domains.

Music interventions have been examined for effects on motor, language, social, cognitive, and academic outcomes. A critical review of 46 studies in children aged roughly 4–13 years found results suggestive of benefit across these domains but concluded that firm conclusions could not yet be drawn [8]. The evidence is

most consistent for executive functions. Three recent meta-analyses report improvements after music training, with inhibitory control showing the most reliable gains [16–18].

Interpretation still requires caution. Studies differ considerably in the type of activity, the age of participants, the duration and frequency of training, the control conditions, and the outcomes measured. Jiang et al., for example, found positive effects on some developmental measures but not consistently across all cognitive assessments [15].

Another key consideration is the distinction between association and causation. Children who take part in music may differ from those who do not in parental involvement, socioeconomic circumstances, educational opportunities, or motivation, so observed differences cannot always be attributed to music alone. This limitation applies to earlier observational work such as that of Forgeard et

al. [14]. A multilevel meta-analysis by Sala and Gobet also found that the apparent cognitive and academic benefits of music training shrank to around zero in better-controlled studies [22]. The most defensible interpretation is therefore that music-based activities are a promising developmental enrichment strategy, rather than a universal intervention that can on its own determine children's cognitive outcomes.

Practical Implications for Parents and Early Childhood Educators

Because musical activities need few resources, they can be built into children's everyday environment with little cost. Parents and educators can sing regularly with children, use rhymes to introduce new words, encourage children to clap or tap rhythms, and combine music with movement. Stop-and-go games can be used to practise inhibitory control, and children can be encouraged to imitate simple rhythms. Songs can be woven into classroom routines, musical storytelling can support language and imagination, and group singing gives children chances to participate together. Children can also be allowed to experiment with simple age-appropriate instruments.

The emphasis should remain on participation and enjoyment rather than performance. A child does not need to sing perfectly, keep a perfect rhythm, or learn a formal instrument to gain meaningful developmental opportunities. This approach may be especially useful where access to specialized developmental programmes is limited, as simple music-based activities can be used in homes, preschools, anganwadi centres, and community programmes without sophisticated equipment.

Limitations

This review has several limitations. As a narrative review, it did not use a systematic search, predefined inclusion criteria, or formal quality appraisal, so the selection of studies may be incomplete and open to bias.

The underlying evidence also has important weaknesses. Studies vary widely in activity type, participant age, intervention dose, control conditions, and outcome measures, which limits direct comparison. Several of the mechanistic findings discussed here, including those on reward processing and sensitive periods, come from studies in adults rather than young children. Many primary studies have small samples, few use random allocation with active control groups, and follow-up is often short.

Publication bias is a further concern. Neves et al. flagged it as a possible explanation for part of the observed effects [19], and an independent re-analysis of the same literature judged the auditory benefits of instrumental training to be suggestive but not conclusive [23]. Effects also appear smaller in better-controlled studies [22]. Finally, little of the evidence comes from India or other low- and middle-income settings, so its applicability to anganwadi and similar programmes remains to be tested.

Future Directions

Future research should prioritise well-designed randomized controlled trials in children under six years, with active control groups, blinded outcome assessment, and pre-registered protocols. Studies should report intervention dose clearly, including duration, frequency, and session length, and use standardised developmental outcome measures so that findings can be compared and pooled.

Direct comparisons between activity types, such as singing, rhythm-based movement, instrumental play, and caregiver-led musical interaction, would help identify which components drive any benefits. Longer follow-up is needed to establish whether effects persist into school age. Child-friendly neurophysiological methods, such as EEG, could clarify mechanisms in young children rather than relying on adult data.

Research in low- and middle-income settings, including Indian preschools and anganwadi centres, should test low-cost, culturally relevant programmes that parents and early childhood workers can deliver. Evaluating feasibility, cost, and effects in children with developmental difficulties would further strengthen the case for practical use.

CONCLUSION

Early childhood is a period of high neural plasticity, and music-based activities offer a promising and accessible way to support several aspects of neurodevelopment. Current evidence is most consistent for executive functions, especially inhibitory control, with smaller and less consistent effects on language, motor, and general cognitive outcomes. Alongside formal music training, everyday experiences such as singing, rhythmic play, movement, clapping, musical storytelling, and shared caregiver-child musical interaction may contribute to development. These activities are best viewed as a low-cost enrichment strategy

that complements, rather than replaces, responsive caregiving and other forms of early learning.

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