

NEUROLOGICAL MUSIC THERAPY (NMT) IN AUTISM SPECTRUM DISORDER (ASD): EVIDENCE, INTERVENTIONS, AND MEASURABLE CLINICAL POSSIBILITIES FOR BRAZIL

Francisco Narthagnan Chaves da Silva¹

Abstract: Autistic Spectrum Disorder (ASD) involves persistent changes in communication, social interaction and restricted and repetitive patterns of behavior. Neurological Music Therapy (Neurologic Music Therapy - NMT) is an international therapeutic model based on neuroscience, composed of 20 standardized techniques that allow measurable interventions in the motor, linguistic and cognitive domains. This article deepens the neurobiological mechanisms underlying the NMT and discusses its applications in ASD, gathering recent scientific evidence that points to gains in motor coordination, attention, engagement and functional communication. Internationally, NMT is recognized as evidence-based practice and used in rehabilitation centers in Canada, the United States and Europe. In Brazil, however, its diffusion is still limited. Based on the experience of the author - neuropsychologist, neurotherapist, behavioral analyst, member of the World Federation for NeuroRehabilitation (WFNR), autistic individual and father of autistic children - this work proposes the NMT as a valid, safe and necessary tool in the field of neurorehabilitation and autism.

Keywords: Neurological Music Therapy. Autism. Neuroscience. Executive functions. Neurodevelopment.

INTRODUCTION

Autistic Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by

¹ Neurologic Music Therapy – NMT) -7118, Neuropsychologist CRP-11/16268, Behavior Analyst (IBAO), Master of Education, PhD in Psychology



persistent deficits in communication and social interaction, as well as by restricted and repetitive patterns of behavior, often accompanied by sensory, motor and cognitive changes. The clinical complexity of ASD requires integrated interventions, based on scientific evidence and able to dialogue with the multiple dimensions involved in child development.

Neurological Music Therapy (Neurologic Music Therapy – NMT) emerges as a systematized, neuroscience-based clinical model that uses music – especially rhythm – to modulate neural networks associated with motricity, language and cognitive functions (THAUT; HOEMBERG, 2014). Comprising of 20 standardized techniques supported by neuroimaging, neurophysiology and rehabilitation studies, NMT differs from other forms of music therapy due to its emphasis on measurement, replicability and standardization of procedures (ACADEMY OF NEUROLOGIC MUSIC THERAPY, 2022).

The author of this article acts as a neuropsychologist, certified neurological music therapist, behavioral analyst and member of the World Federation for NeuroRehabilitation (WFNR), with experience in the evaluation and intervention in children with ASD. In addition, he is an autistic individual and father of autistic children, which gives him a unique perspective on the impact of therapeutic interventions on the daily lives of families.

In countries such as Canada and the United States, NMT is recognized as evidence-based practice and integrates hospital services, rehabilitation centers and programs specialized in autism. In Brazil, however, the approach remains little known, practically absent in the national scientific literature and little explored in public health and education policies.

The aim of this article is to present the NMT as an evidence-based practice applicable to ASD, focusing on: (a) robust theoretical foundation on brain functioning in front of music; (b) description of empirical evidence; (c) analysis of the possibilities of intervention in language, motricity and cognition; and (d) discussion about the need for its diffusion in the Brazilian context.



THEORETICAL FUNDING

Music as a multisystemic neurological experience

Music is one of the most complex stimuli processed by the nervous system. Its structure involves acoustic, temporal and emotional components that simultaneously activate networks distributed by much of the brain. Functional neuroimaging studies show that listening, producing or imagining music triggers:

- the primary and secondary auditory cortex (analysis of sound attributes);
- the pre-motor cortex and supplementary motor areas (planning and movement preparation);
- the motor cortex (implementation of rhythmic and synchronized movements);
- cerebellum (coordination, temporal prediction and rhythmic adjustment);
- the ganglia of the base (sequencing, internal rhythm, selection of actions);
- the limbic system (emotion, motivation and affective memory);
- attention and protrusion networks (relevant stimulus selection and focus maintenance);
- the arched fascicle and perisylvian regions (language, prosody and auditory-motor integration).

The highly integrated nature of music allows it to act as a powerful tool for reorganization of emotional, cognitive, motor and social functions frequently affected dimensions in ASD.

Rhythmic entrainment and temporal prediction

A central concept of the NMT is the rhythmic entry, that is, the ability of the nervous system to synchronize internal patterns (motor, attentional, emotional) to a rhythmically stable external stimulus. In practice, this is observed when a child claps his hands at the time of music, adjusts the



march to a metronome or accompanies with the body the rhythmic pulse of a song.

From a neurobiological point of view, the entry involves:

- temporal prediction (precipitation of the next pulse or accent);
- coupling between auditory cortex, premotor cortex, cerebellum and base ganglia;
- oscillatory coherence (organization of neural oscillations according to external rhythm);
- reduction of motor variability;
- greater stability in behavior control.

In individuals with ASD, difficulties in temporal prediction, motor timing instability and variability in attentional responses are frequent. The musical rhythm, by providing a clear and predictable time pattern, works as an external neurological organizer, decreasing internal processing demand and favoring a more stable synchronization of motor and cognitive responses.

Brain differences in ASD and NMT relevance

Neuroscientific literature indicates that ASD is associated with changes in functional and structural connectivity of the brain, particularly in networks that sustain sensory-motor integration, timing, attention and predictability.

Atypical connectivity

Many studies describe, in ASD, a pattern of local hyperconnectivity and long-distance hypoconnectivity, especially between frontal and posterior regions. This may hinder the integration of sensory, motor and cognitive information, generating sensory overload, difficulty in “uniting the parts” of a situation and challenges in adapting to the context. Music, by structuring the temporal flow of stimuli and reducing unpredictability, helps organize this sensory experience, making it more



predictable and bearable.

Changes in cerebellum and base ganglia

Cerebellum plays a crucial role in motor coordination, temporal prediction and movement adjustment, while base ganglia are involved in sequencing, selection of actions and internal rhythm. In autistic individuals, morphological and functional studies report abnormalities in the cerebellum and base ganglia, which are associated with:

- motor coordination difficulties;
- increased timing variability;
- problems of movement initiation and termination;
- presence of stereotyped and repetitive movements.

These changes make interventions using rhythm and music especially relevant as a way to stimulate and reorganize these networks.

Leaning and attentional control network

The Salience Network, responsible for detecting relevant stimuli and helping the brain to alternate between rest states and focus states, also presents functional differences in ASD. Autistic children often find it difficult to keep their attention in structured tasks, to alternate focus gently or to prioritize important stimuli in a complex environment. Music, because it is highly engaging and predictable, activates this network intensely, facilitating the maintenance of focus, joint attention and engagement in therapeutic activities.



Hypo/Hyper-sensory reactivity

Many children with ASD have hyper or hyporeactivity to sensory stimuli. Music, when used with control of intensity, time and density of information, functions as a graduated and predictable auditory stimulus, which allows:

- reduce anxiety against sounds;
- increase sensory tolerance;
- structure the auditory experience in a less chaotic way.

Music, language and communication

Speech production depends on a complex integration between auditory perception, linguistic processing, motor planning and temporal control of the orofacial muscles. In ASD, especially in cases with speech apraxia, minimal speech or atypical prosody, these steps may be deeply disorganized.

Music plays a privileged role in this context by:

- intensely activate the arched fascicle, which connects receptive and expressive language areas;
- provide a melodic contour (tonal height) and rhythmic (temporal pattern) that organizes the syllable sequence;
- reduce the load of motor planning by turning speech into singing or rhythmic speech.

Techniques like Musical Speech Stimulation (MUSTIM™) use songs, melodic phrases and rhythmic intonations to stimulate propositional speech, taking advantage of the fact that many individuals can sing excerpts from familiar songs even when they have great difficulty to speak spontaneously. The Rhythmic Speech Cueing (RSC®) apply external rhythm (metronome, percussion) to improve prosody, fluency and speech speed, being useful in cases of monotonous speech, accelerated,



fragmented or irregular pauses.

Music, cognition and executive functions

Executive functions – attention, working memory, cognitive flexibility, planning and inhibitory control – are often affected in ASD. Musical stimuli activate prefrontal and temporal regions involved in these functions, offering a rich context for their training.

At NMT, the Musical Attention Control Training (MACTTM) structure musical tasks to train selective attention (reply only to a specific sound pattern), alternating attention (change the focus between different stimuli) and sustained attention (maintain response over time). O Musical Executive Function Training (MEFT®) it uses guided improvisation, composition and organization of musical sequences to train planning, monitoring of behavior and cognitive flexibility, requiring the individual:

- initiate actions;
- maintain sequences;
- adjusts responses to changes in rules;

Share shifts in group musical activities.

Music, emotion and motivation

The limbic system responds intensely to music, which can evoke emotions, memories and alert or relaxation states. In children with ASD, who often have difficulties in emotional regulation, behavioral crises and resistance to traditional interventions, music:

- increases the intrinsic motivation for engagement in activities;
- reduces anxiety;
- improves tolerance to frustrations;



- strengthens the therapeutic bond;
- creates a more predictable and welcoming environment.

Thus, NMT benefits not only from the motor and cognitive effects of music, but also from its motivational and affective impact.

NMT as standardized and evidence-based model

NMT is not an intuitive application of music in the clinic, but a structured model that:

- has 20 standardized techniques distributed in three domains (motor, language and cognition);
- use Transformational Design Model (TDMTM) to transform non-musical objectives into specific and measurable musical tasks;
- requires specific training and international certification;
- it is recognized in neurorehabilitation guidelines in several countries.

This standardization ensures that interventions are replicable, documentable and evaluable, aligning the NMT with the contemporary paradigm of evidence-based practices.

Neurobiological parallels between Parkinson's and ASD in the context of MMT

In countries like the Canada, Neurological Music Therapy (NMT) is widely recognized as evidence-based intervention for conditions such as Parkinson's Disease, being used in neurorehabilitation centers due to its effectiveness in the rehabilitation of motor timing, coordination and temporal prediction (THAUT; ABIRU, 2010). In these applications, NMT directly stimulates structures such as the cerebellum, Base ganglia and routes pre-motors, responsible for motor



sequencing, temporal stability and auditory-motor synchronization.

Although Parkinson and ASD are distinct conditions in their etiology, studies have shown that many autistic children present alterations in these same neurofunctional structures. Studies show consistent abnormalities in the cerebellum in individuals with ASD (FATEMI et al., 2012), as well as dysfunctions in the Base ganglia, associated with difficulties in motor fluency, regulation of repetitive behaviors and temporal processing (FERNANDEZ, 2018). In addition, children with ASD present significant deficits in temporal prediction, motor variability, sequential control of actions and internal timing, patterns that dialogue with changes observed in motor conditions such as Parkinson's disease (MOSCONI et al., 2015).

Grahn and Brett (2007) demonstrate that the processing of rhythm and pulse depends heavily on the integrity of the ganglia of the base, reinforcing the idea that rhythm-based musical interventions can modulate deficits shared by different neurological conditions that affect timing.

Thus, although there are still no direct comparative clinical studies between Parkinson and ASD in the use of MMT, the neuroscientific literature indicates structural and functional parallels sufficiently robust to support the transfer of therapeutic principles of MMT among these populations. The mechanisms by which MTM improves gait, cadence, temporal predictability and coordination in Parkinson's are neurobiologically applicable to deficits observed in children with ASD, such as:

- engine timing instability;
- hypotonia and dyspraxia;
- difficulties in the temporal organization of speech;
- high motor variability;
- behavioral stiffness dependent on repetitive patterns;
- executive deficits related to sequencing and change of task.

Thus, the strong evidence base of MTM in motor conditions such as Parkinson strengthens the neurobiological rationale for its application in ASD, justifying the investment in specific studies



and responsible clinical implementation of this approach with the autistic population.

Author's note:

This articulation between Parkinson and ASD is a theoretical-clinical interpretation based on the literature on timing, cerebellum, base ganglia and auditory-motor processing. Although there is convergent evidence supporting such parallels (FATEMI et al., 2012; FERNANDEZ, 2018; GRAHN; BRETT, 2007; MOSCONI et al., 2015; THAUT; ABIRU, 2010), there are still no studies that directly compare the effects of MMT between these two conditions. Therefore, this analysis should be understood as a plausible and coherent scientific inference, not as established clinical equivalence.

EMT EMPIRICAL EVIDENCES IN THEA

Neurological Music Therapy (NMT) has accumulated evidence that demonstrates its effectiveness in the care of populations with Autistic Spectrum Disorder. Although the literature is still expanding, recent studies point to significant improvements in motor, cognitive, sensory and communicational areas.

Williams et al. (2024) investigated the effects of MMT in children with ASD using nine sessions structured by teleservice. The authors identified statistically significant improvements in motor skills, especially in the coordination and precision of movement, indicating that the mechanisms of entry can be effective even in remote formats.

Cibrian et al. (2020), in a randomized pilot clinical trial, compared two forms of delivery of MMT: (a) use of traditional instruments and (b) use of a tactile-elastic device developed for sensory-motor support. In both groups, they observed improvements in strength, stability, timing, and coordination, reinforcing that the effectiveness of MMT is more associated with its neuroscientific principles than with the type of instrument used.

Mayer-Benarous et al. (2021), in a systematic review, analyzed musical interventions based on the foundations of neuroscience and concluded that they promote consistent benefits in



communication, social engagement, adaptive behavior, motor coordination and attention in children with ASD.

Janzen and Thaut (2018) point out that deficits in temporal prediction — widely recorded in ASD — can be partially compensated by entrainment mechanisms, capable of stabilizing motor and social behaviors through predictable external rhythms.

When structured interventions such as NMT are observed, considering auditory-motor stimulation, the use of rhythm, reinforcement of temporality and sensory organization, a promising window is opened to expand evidence-based clinical interventions in ASD.

NMT INTERVENTIONS IN THEA

NMT organizes its techniques in three functional domains: language, motority and cognition. Each technique has a clear neuroscientific rationale, which explains how music influences specific neural systems.

Interventions for language

In ASD, communication deficits can manifest as echolalia, monotonic prosody, fragmented speech, speech apraxia or partial/total absence of speech. NMT uses:

Musical Speech Stimulation (MUSTIMTM)

He uses family melodic phrases to stimulate propositional speech. The melody reduces the effort of motor planning, facilitating verbal initiation.



Rhythmic Speech Cueing (RSC®)

It uses external rhythm as a metronome to train prosody, fluency and speech cadence. It benefits especially children with apraxia, accelerated speech or deficits in speech temporal organization.

Motricity interventions

Individuals with ASD often have hypotonia, dyspraxia, gait difficulties, coordination problems and motor variability. NMT uses:

Pattern Sensory Enhancement (PSE®)

It uses musical elements (rhythm, dynamics, timbre, height) to guide power, amplitude and direction of movement.

Rhythmic Auditory Stimulation (RAS®)

Improves gait, cadence and postural stability using external rhythm. Evidence suggests that it can also benefit ASD in situations of instability and variation of motor timing.

Therapeutic Instrumental Music Performance (TIMP®)

Training bimanual coordination, strength, precision and range of motion using musical instruments in functional patterns.



Interventions for cognition

Executive functions — attention, memory, planning, flexibility — are greatly impaired in ASD. NMT works these areas with specific techniques:

Musical Attention Control Training (MACTTM)

Trains sustained, selective and alternating attention through responses to specific musical patterns.

Musical Executive Function Training (MEFT®)

It uses improvisation, composition and sequential organization of musical elements to train planning, inhibitory control and cognitive flexibility.

Musical Mnemonics Training (MMTTM)

It employs music as a tool for coding and retrieval of information, facilitating memorization of sequences, routines and academic contents.

Measurable variables in TDMTM

Transformational Design Model allows you to convert therapeutic goals into quantifiable indicators:



Domain	Technique	Clinical Purpose	Measurable Indicator
Language	RSC®	Fluency and prosody	Synchronized syllables %; cadence
Engine	PSE®	Amplitude and force of movement	ROM; isometric force
Engine	TIMP®	Bi-manual coordination	the number of hits;
Cognition	MACTTM	Selective/sustained attention	latency; rate of hits
Cognition	MEFT®	Planning / flexibility	number of sequences; changes

INTERNATIONAL USE OF NMT IN TEA SERVICES

The NMT has consolidated presence in three regions:

Canada – Reference centres

Example: Con Brio Music Therapy

Application of MMT in communication programs, motor coordination and emotional regulation in children with ASD.

United States – Specialized clinics

Example: Optimal ACCESS

It integrates MMT as a central component in the multidisciplinary treatment of autism.

Europe – Neurorehabilitation Guidelines

The World Federation for NeuroRehabilitation (WFNR) recognizes the NMT as an evidence-based approach to neuromotor disorders — justifying its expanded application to ASD populations due to neurobiological overlaps in the cerebellum-ganglia systems of the base.



These international models serve as a reference for the safe and qualified implementation of NMT in Brazil.

CONCLUSION

Neurological Music Therapy (NMT) is one of the most promising and scientifically based interventions for Autistic Spectrum Disorder. Its use of rhythm, temporal organization and auditory-motor stimuli acts directly in neural systems frequently affected in ASD, including cerebellum, base ganglia, arched fascicle and attention networks.

The comparison with Parkinson's disease, widely supported by evidence, contributes to strengthen the neurobiological rationale of MTMN in autism, since both conditions share deficits in temporal prediction, motor variability and internal rhythm stability.

The efficacy demonstrated in international studies, together with the evidence emerging in ASD, points out that Brazil needs to advance the implementation and study of MTM as a structured, replicable and evidence-based intervention.

The adoption of NMT in the country requires scientific investment, specialized training and integration in public health and education policies. With its broad applicability, predictability and strong neurobiological basis, the NMT stands as an innovative, necessary and ethical tool to support the development of autistic children and adolescents in Brazil.

REFERENCES

ACADEMY OF NEUROLOGIC MUSIC THERAPY. Standards of Practice. Colorado, 2022. Available in: <https://nmtacademy.co>. Access: 20 Jan. 2025.

CIBRIAN, F. L. et al. Supporting coordination of children with Autism Spectrum Disorder using Neurologic Music Therapy. *Research in Developmental Disabilities*, v. 105, p. 103732, 2020.



CON BRIO MUSIC THERAPY. Clinical Services Overview. Available at: <https://www.conbriotmt.com>. Access: 20 Jan. 2025.

FATEMI, S. H. et al. Consensus Report: Pathological Role of the Cerebellum in Autism. *Cerebellum*, v. 11, n. 3, p. 777–807, 2012.

FERNANDEZ, J. Basal Ganglia Dysfunction in Autism. *Frontiers in Integrative Neuroscience*, v. 12, p. 23, 2018.

GRAHN, J.A.; BRETT, M. Rhythm and beat processing really on the basal ganglia. *Journal of Cognitive Neuroscience*, v. 19, n. 5, p. 893–905, 2007.

JANZEN, T. B.; THAUT, M. H. Music and neurodevelopment in autism: towards a holistic model. *Music & Science*, v. 1, p. 1–15, 2018.

MAYER-BENAROUS, H. et al. Music therapy for children with autism spectrum disorders: A systematic review. *Frontiers in Psychiatry*, v. 12, 2021.

MOSCONI, M. W. et al. Sensorimotor abnormalities and motor timing deficits in autism spectrum disorder. *Journal of Neurodevelopmental Disorders*, v. 7, n. 1, p. 28, 2015.

NMT ACADEMY. Evidence-Based Clinical Applications of Neurologic Music Therapy. Available in: <https://nmtacademy.co>. Access: 20 Jan. 2025.

OPTIMAL ACCESS. Neurologic Music Therapy Services for Autism. Available at: <https://optimalaccess.org>. Access: 20 Jan. 2025.

ROSSIGNOL, D.; FRYE, R. [Title of the article on neurobiological basis of ASD]. *Molecular Psychiatry*, 2012. Complete data to be checked.

THAUT, M. H.; ABIRU, M. Rhythmic Auditory Stimulation in Motor Rehabilitation: A Review of Current Research. *Music Perception*, v. 27, n. 4, p. 263–269, 2010.

THAUT, M. H.; HOEMBERG, V. *Handbook of Neurologic Music Therapy*. Oxford: Oxford University



Press, 2014.

WAN, C. Y.; SCHLAUG, G. Music making as a tool for promoting brain plasticity across the life span. *The Neuroscientist*, v. 16, n. 5, p. 566–577, 2010.

WILLIAMS, N. et al. Motor skills improvements following Neurologic Music Therapy in children with Autism Spectrum Disorder. *Frontiers in Psychology* 2024.

WORLD FEDERATION FOR NEUROREHABILITATION (WFNR). Neurorehabilitation Guidelines. Available in: <https://www.wfnr.co.uk>. Access: 20 Jan. 2025.

