



THE DRUM PROTOCOLS

Research Citations Reference Guide

Complete Evidence Base with Abstracts & DOIs

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Total Papers: 44 · Spanning 2005–2026

NOTE: *This document is a quick reference guide organized by research topic, providing the complete scientific evidence base for The Drum Protocols therapeutic rhythmic entrainment system. It is not a peer-reviewed publication. Research Access: <https://bit.ly/the-drum-protocols-research>*

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1. FOUNDATIONAL NEUROSCIENCE: BRAIN RHYTHM MECHANISMS

1.1 Welsh et al. (2005) — The Foundational Paper

Journal: International Journal of Developmental Neuroscience

DOI: <https://doi.org/10.1016/j.ijdevneu.2004.09.002>

Title: "Is autism due to brain desynchronization?"

Welsh and colleagues proposed the desynchronization hypothesis, identifying the inferior olive as the primary locus of dysfunction in autism. The inferior olive normally generates 5–13 Hz oscillatory rhythms critical for cerebellar timing, motor coordination, and temporal processing. This rhythmic generation system is disrupted in autism, leading to desynchronized neural activity across multiple brain regions. The 5–13 Hz range coordinates

motor timing/sequencing, temporal prediction, sensory integration across modalities, and social timing/interpersonal synchrony.

Critical Finding: *The Drum Protocols' 7 Hz target falls precisely in the MIDDLE of the 5–13 Hz disruption range identified by Welsh.*

1.2 Dickinson et al. (2025) — Most Recent Developmental Evidence

Journal: Developmental Science

DOI: <https://doi.org/10.1111/desc.13593>

Title: "Accelerated Infant Brain Rhythm Maturation in Autism"

Longitudinal EEG study (3, 6, 9, 12 months) in 87 infants, 51 at higher familial likelihood for autism. Functional principal component analysis revealed power increases between 6–9 Hz accounted for over 71% of variance in infant spectral maturation. Infants later diagnosed with autism showed accelerated rhythm maturation in this frequency band—steeper trajectory between 3–12 months ($p < 0.001$). The typical sequence is preserved but timing is altered. Age-related changes consistent regardless of familial likelihood, suggesting differences in oscillatory timing associated with autism outcomes rather than genetic predisposition.

Critical Finding: *Confirms altered timing (not absence) of rhythm development in the 6–9 Hz band, which overlaps The Drum Protocols' 7 Hz target.*

1.3 Neo et al. (2023) — Largest Meta-Analysis

Journal: Translational Psychiatry (Nature)

DOI: <https://doi.org/10.1038/s41398-023-02681-2>

Title: "Resting-state EEG power differences in autism spectrum disorder: a systematic review and meta-analysis"

Meta-analysis of 41 studies involving 1,246 autistic and 1,455 neurotypical individuals across 135 effect sizes. Ten meta-analyses examined absolute and relative power in delta, theta, alpha, beta, and gamma bands. Key findings: autistic individuals exhibited reduced relative alpha ($g = -0.35$) and increased gamma power (absolute: $g = 0.37$, relative: $g = 1.06$ — large effect). No significant differences in delta, theta (population level), absolute alpha, or beta. Substantial heterogeneity observed.

Critical Finding: *Population-level confirmation of reduced alpha (7–13 Hz), supporting alpha/gamma as potential biomarkers.*

1.4 Ippolito et al. (2022) — Cross-Disorder Review

Journal: Biomedicines

DOI: <https://doi.org/10.3390/biomedicines10123189>

Title: "The Role of Alpha Oscillations among the Main Neuropsychiatric Disorders in the Adult and Developing Human Brain"

Review of last 10 years of research on alpha oscillations (7–13 Hz) across neuropsychiatric disorders including autism, schizophrenia, major depression, and ADHD. Alpha = dominant rhythm in resting and active brain. Evidence for aberrant alpha activity in onset of symptomatology across syndromes. Difficult to reconcile findings due to paradigm variety, but confirms alpha rhythm alterations as core mechanism across disorders.

Critical Finding: *7–13 Hz alpha band central across multiple neuropsychiatric conditions, not autism-specific.*

1.5 Strang et al. (2022) — Mu Rhythm & Autism Traits

Journal: Frontiers in Neuroscience

DOI: <https://doi.org/10.3389/fnins.2022.950539>

Title: "Peak frequency of the sensorimotor mu rhythm varies with autism-spectrum traits"

High-density 128-channel EEG (n=60 neurotypical participants) during motor execution (bimanual finger tapping) and action observation (viewing whole-body movements). Mu rhythm = alpha-band (8–12 Hz) oscillation over sensorimotor cortex showing suppression during own movements and observation of others' actions. Mu suppression thought to reflect integration of perceptual/motor representations for understanding others' mental states. Higher autism-spectrum traits associated with slowing of peak mu frequency (PMF). PMF highly reliable within participants, not driven by resting vs task states.

Critical Finding: *Individual peak oscillatory alpha-band frequency = correlate of autism traits in neurotypical population.*

1.6 Jones et al. (2020) — Infant Theta Predicts Intelligence

Journal: Scientific Reports (Nature)

DOI: <https://doi.org/10.1038/s41598-020-67687-y>

Title: "Infant EEG theta modulation predicts childhood intelligence"

Three independent cohorts (discovery TD + two replication enriched for autism familial risk). 12-month-old infants, theta power (3–6 Hz) during dynamic videos. Frontal theta significantly increased during video viewing. Individual differences in magnitude of theta change related to concurrent nonverbal cognitive level. Predictive relation to verbal and nonverbal cognitive skills at ages 2, 3, and 7 years. For high-risk infants later diagnosed with autism: infant theta EEG explained >80% variance in nonverbal skills at age 3.

Critical Finding: *Theta (3–6 Hz) = excellent predictive biomarker, especially powerful for autism outcomes.*

1.7 Taweeseedt et al. (2025) — Theta at Sleep Onset

Journal: Journal of Autism and Developmental Disorders

DOI: <https://doi.org/10.1007/s10803-025-07013-5>

Title: "Theta Activity at Sleep Onset in Children with Autism Spectrum Disorder"

Polysomnography study (n=60 ASD ages 5.6–18.3 vs n=70 TD controls). TASSO prevalence: 30% in ASD vs 6% in TD controls (5× higher). TASSO(+) group scored significantly worse on affect recognition test with large effect size (18.6 vs 23.5, $t=2.30$, $p=0.027$, $d=0.75$). TASSO not associated with other cognitive/affective measures but trend toward worse daytime behavior. TASSO = objective sleep feature in ASD, potential mechanism linking poor sleep to ASD symptom severity, especially social cognition.

Critical Finding: *Theta rhythm dysregulation extends to sleep-wake transitions, linking to social cognition deficits.*

1.8 Kawasaki et al. (2017) — Theta & Motor Synchronization

Journal: Scientific Reports (Nature)

DOI: <https://doi.org/10.1038/s41598-017-14508-4>

Title: "Frontal theta activation during motor synchronization in autism"

EEG during cooperative tapping task (tap alternately/synchronously with constant rhythmic PC program, variable rhythmic PC program, or human partner). Autistic individuals had great difficulty synchronizing tapping with others. Greater than normal theta-wave (6 Hz) activity in frontal cortex during task, especially with irregular behavior (variable PC or human partner). Critical: higher theta activity related to severity of autism, not task performance. People with autism need intense cognition to adapt to irregular behavior and can easily become overtaxed.

Critical Finding: *Unifying theory — both social deficits and repetitive behaviors explained by difficulties with irregularities. Theta (6 Hz) = compensatory cognitive effort marker.*

1.9 Buzzell et al. (2022) — Mediofrontal Theta & Cognitive Control

Journal: Biological Psychiatry: Cognitive Neuroscience and Neuroimaging

DOI: <https://doi.org/10.1016/j.bpsc.2021.03.016>

Title: "Atypical Mediofrontal Theta Oscillations Underlying Cognitive Control in Kindergarteners With Autism Spectrum Disorder"

EEG during flanker task in kindergarteners with ASD (n=29) vs neurotypical controls (n=50). ASD group showed delayed mediofrontal theta response—significant interaction between diagnosis and time (100–200 ms vs 200–300 ms post-stimulus). Late onset suggests atypical temporal dynamics of cognitive control processes, not absence. Effect specific to theta band, not observed in alpha/beta. Individual differences in theta timing correlated with parent-reported executive function difficulties in daily life.

Critical Finding: *Timing of theta oscillations, not just power, is altered in autism—supports temporal dysregulation hypothesis.*

1.10 Fan et al. (2023) — Rhythmic Attentional Sampling

Journal: Autism Research

DOI: <https://doi.org/10.1002/aur.3021>

Title: "Rhythmic attentional sampling in autism"

Behavioral and psychophysical study of rhythmic attention in ASD (n=24) vs neurotypical (n=24) young adults. Autistic participants showed intact theta-rhythmic attentional sampling (no group differences in rhythmicity or phase-dependent performance). However, autistic group showed reduced overall attentional precision (higher thresholds). Results suggest attention oscillates normally but with reduced gain/precision, not disrupted rhythm per se.

Critical Finding: *Important null finding—basic rhythmic sampling intact, but precision/gain reduced. Supports scaffolding over rhythm-generation deficit.*

2. TIMING & RHYTHM AS CORE DEFICIT

2.1 Jurek et al. (2019) — Comprehensive Timing Review

Journal: Behavioural Brain Research

DOI: <https://doi.org/10.1016/j.bbr.2019.112121>

Title: "Timing deficits in autism: a comprehensive review"

Comprehensive review of timing across multiple domains in autism: millisecond timing, duration discrimination, temporal integration, motor timing, temporal order judgment, time reproduction/estimation, and circadian rhythms. Consistent evidence for timing deficits across sub-second and supra-second intervals. Strongest evidence in motor timing (tapping, synchronization), temporal reproduction, and circadian regulation. Links timing deficits to cerebellar and basal ganglia dysfunction. Proposes timing as a potential endophenotype—a measurable component along the path between genes and behavior.

Critical Finding: *Timing difficulties span multiple temporal scales and multiple functional domains, supporting timing as core feature.*

2.2 Lense et al. (2021) — Rhythm and Timing as Vulnerabilities

Journal: Philosophical Transactions of the Royal Society B

DOI: <https://doi.org/10.1098/rstb.2020.0327>

Title: "Rhythm and timing as vulnerabilities in neurodevelopmental disorders"

Cross-disorder review examining rhythm/timing difficulties in autism, ADHD, dyslexia, and developmental language disorder. Strong evidence for beat perception/synchronization deficits in autism and dyslexia. Timing difficulties linked to language, motor, and social communication symptoms across disorders. Individual differences in rhythm abilities correlate with symptom severity. Proposes rhythm/timing as transdiagnostic vulnerability with

disorder-specific manifestations. Highlights potential for rhythm-based interventions targeting shared underlying mechanisms.

Critical Finding: *Positions rhythm as transdiagnostic target, not autism-specific—broadens intervention relevance.*

2.3 Tordjman et al. (2015a) — Time Perceptions and Representations

Journal: Encephale

DOI: [https://doi.org/10.1016/S0013-7006\(15\)30001-4](https://doi.org/10.1016/S0013-7006(15)30001-4)

Title: "Time perceptions and representations"

Theoretical review of temporal processing and perception in autism. Examines subjective time experience, duration judgment, temporal succession, and temporal integration. Proposes that altered time perception may contribute to difficulties with change, transitions, and sequential processing. Links temporal processing to executive function, working memory, and predictive coding. Discusses implications for understanding restricted/repetitive behaviors as attempts to maintain temporal predictability.

Critical Finding: *Connects micro-level timing deficits to macro-level autism phenomenology—predictability needs, routine rigidity, transition difficulties.*

2.4 Tordjman et al. (2015b) — Biological and Behavioral Rhythms

Journal: Frontiers in Pediatrics

DOI: <https://doi.org/10.3389/fped.2015.00001>

Title: "Autism as a disorder of biological and behavioral rhythms: toward new therapeutic perspectives"

Comprehensive framework proposing autism involves dysregulation across multiple rhythmic systems: circadian rhythms (sleep-wake, melatonin), ultradian rhythms (90-minute cycles), motor rhythms (gait, stereotypies), social rhythms (turn-taking, synchrony), and neural oscillations. Review of evidence for rhythm dysregulation across all these domains. Proposes chronotherapy and rhythm-based interventions as therapeutic targets. Links rhythm dysregulation to core symptoms: social timing deficits ↔ social communication difficulties; motor rhythm alterations ↔ stereotypies; circadian disruption ↔ sleep problems and behavioral regulation.

Critical Finding: *Multi-level rhythm dysregulation framework—autism as timing disorder across nested temporal scales.*

2.5 Trevarthen & Daniel (2005) — Early Signs in Rhythm/Synchrony

Journal: Brain and Development

DOI: <https://doi.org/10.1016/j.braindev.2005.03.016>

Title: "Disorganized rhythm and synchrony: Early signs of autism and Rett syndrome"

Detailed observational and theoretical analysis of early infant movement, interaction patterns, and developmental timing in autism and Rett syndrome. Proposes that difficulties in temporal coordination and interpersonal synchrony are among the earliest detectable signs. Examines disrupted rhythms in: infant movement quality/organization, proto-conversation timing (turn-taking, gaze coordination), emotional expression timing, and joint attention emergence.

Critical Finding: *Positions rhythm disruption as early developmental marker visible in infancy, not later-emerging consequence.*

2.6 Cannon et al. (2023) — Rhythmic vs Interval Timing

Journal: Autism Research

DOI: <https://doi.org/10.1002/aur.2892>

Title: "Rhythmic and interval-based temporal orienting in autism"

Psychophysical study (n=30 ASD, n=30 neurotypical adults) comparing rhythmic (beat-based) versus interval (duration-based) temporal prediction. Neurotypical group showed larger benefits from rhythmic than interval cues. ASD group showed equal benefit from both types—suggesting compensatory shift toward explicit interval timing rather than implicit rhythm-based prediction. Individual differences in autism symptom severity correlated with degree of rhythmic timing difficulty.

Critical Finding: *Suggests autism involves preference/reliance on explicit interval timing over implicit rhythmic entrainment—important for intervention design.*

2.7 Fram et al. (2024) — Rhythm in Social Communication Development

Journal: Autism Research

DOI: <https://doi.org/10.1002/aur.3090>

Title: "The role of rhythm in social communication development in toddlers with and without autism spectrum disorder"

Longitudinal study of toddlers (18–36 months) with ASD (n=31) and neurotypical development (n=40). Neurotypical toddlers: rhythmic synchrony at 18 months predicted expressive language growth 18 months → 36 months. ASD group: no predictive relationship between early rhythmic synchrony and later communication outcomes. Results suggest rhythm-communication developmental link is altered or absent in ASD—rhythm is not scaffolding communication development in typical fashion.

Critical Finding: *Rhythm-to-language developmental pathway may be disrupted in autism, not just delayed—implications for early intervention targets.*

3. SYNCHRONY & SOCIAL TIMING DEFICITS

3.1 Kwon & Kotani (2025) — Body Motion Synchrony Biomarker

Journal: Diagnostics

DOI: <https://doi.org/10.3390/diagnostics15101268>

Title: "Quantifying body motion synchrony in autism spectrum disorder using a phase difference detection algorithm: Toward a novel behavioral biomarker"

Developed computational method (phase difference detection algorithm) to quantify interpersonal motion synchrony during social interaction. Applied to video recordings of ASD (n=34) and neurotypical (n=34) children during play with therapist. ASD group showed significantly reduced motion synchrony across multiple body regions. Synchrony metrics correlated with autism symptom severity (ADOS scores). Machine learning classification using synchrony features achieved 82.4% accuracy distinguishing ASD from neurotypical.

Critical Finding: *Interpersonal motor synchrony is quantifiable, reduced in autism, and correlates with symptom severity—potential objective outcome measure.*

3.2 Daniel et al. (2022) — Rhythmic Relating Framework

Journal: Frontiers in Psychology

DOI: <https://doi.org/10.3389/fpsyg.2022.793258>

Title: "Rhythmic relating: Bidirectional support for social timing in autism therapies"

Multi-author perspective paper proposing 'Rhythmic Relating' framework for autism intervention. Core premise: social interaction is fundamentally rhythmic/temporal—turn-taking, joint attention, conversation, play all require temporal coordination. Autism involves bidirectional timing difficulties: (1) autistic person struggles to synchronize with partner's timing, and (2) neurotypical partner struggles to synchronize with autistic person's timing. Therapeutic approach: establish shared rhythmic ground through music, movement, drumming as foundation for building social connection. Neurodiversity-affirming stance: values autistic timing as different but valid.

Critical Finding: *Positions social timing as bidirectional challenge requiring mutual adaptation, not deficit-only*

3.3 Christensen (2021) — Syncopation as Cultural Framework

Journal: Culture, Medicine, and Psychiatry

DOI: <https://doi.org/10.1007/s11013-020-09698-y>

Title: "Synchronization and syncopation: Conceptualizing autism through rhythm"

Cultural/anthropological analysis using musical concepts of synchronization and syncopation as non-pathological framework for autism. Synchronization = matching others' timing (typical expectation). Syncopation = emphasis on off-beats, creating tension/interest in music. Proposes autistic temporal experience as syncopated relative to neurotypical synchronization—not disordered but differently ordered. Challenges pathologizing framing while acknowledging real coordination difficulties. Explores how social environments can become more rhythmically flexible to accommodate temporal diversity.

Critical Finding: *Offers non-pathological cultural framework for temporal differences, supporting neurodiversity perspectives.*

4. RHYTHM-BASED INTERVENTION STUDIES (RCTS)

4.1 Bieleninik et al. (2017) — TIME-A Trial (JAMA)

Journal: JAMA

DOI: <https://doi.org/10.1001/jama.2017.9478>

Title: "Effects of improvisational music therapy vs enhanced standard care on symptom severity among children with autism spectrum disorder: The TIME-A randomized clinical trial"

Large-scale international RCT (N=364 children aged 4–7 years across 9 countries). Improvisational music therapy (3 times/week, 5 months) vs enhanced standard care. Primary outcome: autism symptom severity (ADOS, SRS). Music therapy showed no significant effect on symptom severity measures. However, exploratory analysis found improvement in social affect domain for subset analysis. Parent-reported quality of life improved significantly in music therapy group. High adherence (91%). Well-powered study, rigorous methodology.

Critical Finding: *Critical null finding—large, rigorous trial found no effect on core symptoms, despite theoretical rationale. Essential for balanced perspective.*

4.2 Srinivasan et al. (2015) — Rhythm + Robotic RCT

Journal: Research in Autism Spectrum Disorders

DOI: <https://doi.org/10.1016/j.rasd.2015.07.004>

Title: "The effects of rhythm and robotic interventions on the imitation/praxis, interpersonal synchrony, and motor performance of children with autism spectrum disorder (ASD): A pilot randomized controlled trial"

Pilot RCT (N=36 children with ASD, ages 5–12 years). Three conditions: rhythm intervention (music, drumming, movement), robotic intervention (imitation games with NAO robot), standard of care. 8 weeks, 2x/week. Both rhythm and robotic groups improved significantly on imitation/praxis compared to standard care. Rhythm group showed unique improvements in interpersonal synchrony (phase locking, cross-correlation during drumming with partner). Motor performance improved in both intervention groups.

Critical Finding: *Rhythm intervention specifically improved interpersonal synchrony beyond imitation skills—supports social timing hypothesis.*

4.3 Srinivasan et al. (2016) — Rhythm Intervention Communication Outcomes

Journal: Research in Autism Spectrum Disorders

DOI: <https://doi.org/10.1016/j.rasd.2016.04.001>

Title: "The effects of embodied rhythm and robotic interventions on the spontaneous and responsive verbal communication skills of children with autism spectrum disorder (ASD): A further outcome of a pilot randomized controlled trial"

Follow-up analysis from Srinivasan et al. 2015 RCT examining communication outcomes. Rhythm group showed significant improvements in spontaneous verbal communication frequency and linguistic complexity compared to control. Effect sizes moderate to large ($d=0.52-0.78$). Improvements maintained at 1-month follow-up. Robotic group showed smaller effects. Mechanism proposed: rhythmic synchrony scaffolds attention and engagement, creating opportunities for communication practice.

Critical Finding: *Rhythm intervention shows promise for communication outcomes, not just motor/social timing—broader impact.*

4.4 Cahart et al. (2022) — Drumming Intervention (PNAS)

Journal: Proceedings of the National Academy of Sciences

DOI: <https://doi.org/10.1073/pnas.2106244119>

Title: "The effect of learning to drum on behavior and brain function in autistic adolescents"

RCT in autistic adolescents ($N=36$, ages 16–20). Drumming intervention (rock drumming lessons, 2x/week, 8 weeks) vs standard support. Drumming group showed significant improvements in inhibitory control (Stop Signal Task) compared to control. fMRI: increased connectivity in auditory-motor networks, reduced hyperconnectivity in default mode network. Neural changes correlated with behavioral improvements. No change in autism symptoms per se, but improved self-regulation capacity.

Critical Finding: *First evidence of rhythm intervention changing brain connectivity in autism—supports neuroplasticity hypothesis.*

4.5 Yoo & Kim (2018) — Dyadic Drum Playing RCT

Journal: Journal of Music Therapy

DOI: <https://doi.org/10.1093/jmt/thy013>

Title: "Dyadic drum playing and social attention in children with autism spectrum disorder: A pilot randomized controlled trial"

Pilot RCT ($N=36$ children with ASD, ages 3–5 years). Dyadic drum playing intervention (child + therapist, rhythmic turn-taking) vs shared book reading control. 12 sessions, 2x/week. Drumming group showed significantly greater increase in social attention duration and frequency (effect sizes $d=0.88-1.24$, large). Improvements generalized to free play without drumming.

Critical Finding: *Drumming specifically targets joint attention/social attention—potential mechanism for social communication gains.*

4.6 LaGasse et al. (2019) — Music Therapy Sensory Gating

Journal: Journal of Music Therapy

DOI: <https://doi.org/10.1093/jmt/thz008>

Title: "Assessing the impact of music therapy on sensory gating and attention in children with autism: A pilot and feasibility study"

Pilot study ($N=15$ children with ASD, ages 6–12) examining neurophysiological effects of music therapy. Music therapy intervention (12 weeks) + EEG measurement of sensory gating (P50 suppression ratio) and attention (P3 amplitude). Trend toward improved sensory gating (P50 ratio) after intervention ($p=0.09$). Significant improvement in attention/orienting (P3 amplitude increased, $p=0.04$). Feasibility demonstrated (90% retention). First study linking music therapy to neurophysiological markers in autism.

Critical Finding: *Preliminary evidence that rhythm/music therapy may modulate basic sensory processing, not just behavioral outcomes.*

4.7 Lowry et al. (2018) — Rock Drumming Behavioral Outcomes

Journal: International Journal of Developmental Disabilities

DOI: <https://doi.org/10.1080/20473869.2018.1429041>

Title: "Rock drumming enhances motor and psychosocial skills of children with emotional and behavioral difficulties"

Quasi-experimental study in children with emotional/behavioral difficulties including ADHD/autism features (N=36, ages 9–17). 10-week rock drumming program vs waitlist control. Drumming group showed significant improvements in manual dexterity, ball skills, balance (motor), and prosocial behavior, hyperactivity reduction, emotional symptoms (psychosocial). Effect sizes medium to large ($d=0.61-0.89$). Participants reported increased confidence and social connection.

Critical Finding: *Drumming benefits extend beyond motor skills to emotional regulation and social behavior—multi-domain impact.*

5. SYSTEMATIC REVIEWS & META-ANALYSES

5.1 Navarro et al. (2025) — Most Recent Meta-Analysis

Journal: Frontiers in Integrative Neuroscience

DOI: <https://doi.org/10.3389/fnint.2025.1673618>

Title: "The effect of music interventions in autism spectrum disorder: A systematic review and meta-analysis"

Systematic review and meta-analysis of music-based interventions in ASD (21 studies, N=1,188 participants). Significant overall effect on social communication (SMD=0.48, 95% CI 0.22–0.74, moderate effect). Larger effects for drumming/rhythm interventions vs general music therapy. Effects for motor skills (SMD=0.61) and emotional regulation (SMD=0.39). High heterogeneity across studies. Recommends standardized protocols and 'personalized, neurodiversity-affirming therapeutic models.'

Critical Finding: *Meta-analytic support for rhythm-based interventions, especially drumming, with specific recommendation for neurodiversity-affirming approaches.*

5.2 Ding et al. (2024) — Rhythm-Based Interventions Meta-Analysis

Journal: Frontiers in Psychiatry

DOI: <https://doi.org/10.3389/fpsyt.2024.1436170>

Title: "The benefit of rhythm-based interventions for individuals with autism spectrum disorder: A systematic review and meta-analysis with random controlled trials"

Meta-analysis of RCTs examining specifically rhythm-based interventions (drumming, rhythmic movement, music with strong rhythmic component) in ASD. 16 RCTs included, N=686 participants. Significant pooled effect size for social interaction ($g=0.52$, moderate) and motor skills ($g=0.67$, medium-large). Smaller but significant effects for communication ($g=0.34$). Subgroup analysis: interactive interventions (dyadic drumming, partner rhythm activities) showed larger effects than individual practice.

Critical Finding: *Specifically rhythm-focused meta-analysis showing moderate effects, with interactive/synchrony-based approaches superior to solo practice.*

5.3 Menezes DeJesus et al. (2020) — Rhythm Interventions Systematic Review

Journal: Complementary Therapies in Medicine

DOI: <https://doi.org/10.1016/j.ctim.2020.102299>

Title: "Rhythm interventions for autism spectrum disorder: A systematic review"

Systematic review of rhythm-based interventions in ASD (13 studies included—RCTs, quasi-experimental, pre-post designs). Majority of studies (11/13) reported positive effects in at least one outcome domain. Most consistent improvements in motor skills and social interaction. Variable quality across studies (lack of control groups, small samples, short intervention periods in many studies). Calls for larger, longer-duration RCTs with standardized outcome measures.

Critical Finding: *Early systematic review establishing promise but noting methodological limitations of rhythm intervention research.*

5.4 Geretsegger et al. (2022) — Cochrane Review Music Therapy

Journal: Cochrane Database of Systematic Reviews

DOI: <https://doi.org/10.1002/14651858.CD004381.pub4>

Title: "Music therapy for autistic people"

Cochrane systematic review and meta-analysis of music therapy interventions in autism (26 studies, N=1,165 participants). Low to moderate quality evidence suggesting music therapy may improve social interaction and communication skills in short term. Very uncertain about longer-term benefits or symptom severity reduction. High risk of bias in many studies (lack of blinding, selective reporting). Concludes evidence is insufficient to support or refute use of music therapy for core autism symptoms.

Critical Finding: *Critical—Cochrane review finds insufficient high-quality evidence for music therapy in autism. Essential balanced perspective.*

6. INTACT RHYTHMIC CAPACITIES (IMPORTANT NULL FINDINGS)

6.1 Knight et al. (2020) — Intact Rhythm Prediction Error

Journal: Autism Research

DOI: <https://doi.org/10.1002/aur.2362>

Title: "Individuals with autism have no detectable deficit in neural markers of prediction error when presented with auditory rhythms of varied temporal complexity"

EEG study examining Mismatch Negativity (MMN) to rhythmic violations in ASD (n=27) vs neurotypical (n=24) young adults. MMN = automatic neural response to violations of rhythmic expectancy (omitted beats, timing deviations). Tested simple and complex rhythmic patterns. No group differences in MMN amplitude or latency for either simple or complex rhythms. Both groups showed robust, equivalent MMN responses. Conclusion: basic neural machinery for detecting rhythmic violations is intact in autism—deficit is not in rhythm prediction per se.

Critical Finding: *Important null finding—basic rhythmic prediction error detection is preserved. Problem may be in using predictions for action, not generating predictions.*

7. NEUROPLASTICITY & BIOMARKER EVIDENCE

7.1 Jannati et al. (2020) — Theta-Burst Stimulation in Children

Journal: Frontiers in Integrative Neuroscience

DOI: <https://doi.org/10.3389/fnint.2020.00013>

Title: "Continuous theta-burst stimulation in children with high-functioning autism spectrum disorder and typically developing children"

TMS study using continuous theta-burst stimulation (cTBS) to examine cortical plasticity in ASD children (n=13, ages 8–12) vs neurotypical (n=14). Neurotypical children showed expected MEP suppression after cTBS. ASD group showed no suppression—cortical plasticity induction was impaired. Individual differences in plasticity response correlated with autism symptom severity (ADOS).

Critical Finding: *Demonstrates altered cortical plasticity mechanisms in autism at neurophysiological level—potential therapeutic target and biomarker.*

7.2 Jannati et al. (2021) — Theta-Burst in Adults

Journal: Clinical Neurophysiology

DOI: <https://doi.org/10.1016/j.clinph.2021.03.021>

Title: "Modulation of motor cortical excitability by continuous theta-burst stimulation in adults with autism spectrum disorder"

Follow-up TMS study in ASD adults (n=15) vs neurotypical adults (n=13). Adults with ASD showed similar pattern to children—impaired suppression after cTBS compared to neurotypical controls. Effect not explained by baseline excitability differences. Suggests plasticity alterations persist into adulthood. Cortical plasticity measures correlated with sensory sensitivity and repetitive behaviors.

Critical Finding: *Confirms altered plasticity is not just developmental phase but persists into adulthood—implicates ongoing neural mechanisms.*

7.3 Kaokhieo et al. (2023) — 5-Hz rTMS + Observation-Execution

Journal: Brain Research

DOI: <https://doi.org/10.1016/j.brainres.2023.148258>

Title: "Effects of repetitive transcranial magnetic stimulation combined with action-observation-execution on social interaction and communication in autism spectrum disorder: Feasibility study"

Pilot feasibility study (n=10 children with ASD, ages 6–10). Intervention: 5-Hz rTMS over left dorsolateral prefrontal cortex + action observation-execution training. 10 sessions over 2 weeks. Significant improvements in SRS-2 total score (d=0.92, large effect) and social communication domain (d=1.15). Improvements in motor imitation accuracy. High feasibility/acceptability. 5-Hz = theta frequency targeting.

Critical Finding: *Preliminary evidence that theta-frequency brain stimulation + behavioral training may enhance social outcomes—supports rhythm targeting.*

7.4 Blank et al. (2025) — Accelerated Theta Burst for Depression in ASD

Journal: Journal of Autism and Developmental Disorders

DOI: <https://doi.org/10.1007/s10803-024-06244-2>

Title: "Accelerated theta burst transcranial magnetic stimulation for refractory depression in autism spectrum disorder"

Case series (n=8 adolescents/young adults with ASD and treatment-refractory depression). Accelerated theta-burst TMS protocol (multiple sessions per day, 5 days, targeting dorsolateral prefrontal cortex). 6/8 participants showed clinically significant depression improvement (>50% MADRS reduction). Effects maintained at 1-month follow-up for 5/6 responders. No worsening of autism symptoms. Well-tolerated.

Critical Finding: *Theta-frequency brain stimulation is safe and potentially effective in ASD, even for comorbidity treatment—expands theta-targeting rationale.*

7.5 Anninos et al. (2019) — Picotesla TMS for Beta-Gamma

Journal: Maedica

DOI: <https://doi.org/10.26574/maedica.2019.14.4.332>

Title: "The effect of pT-TMS on beta rhythm in children with autism disorder: A MEG study"

Pilot study (n=7 children with ASD, ages 6–9) using picotesla transcranial magnetic stimulation (extremely low intensity, non-invasive) targeting beta-gamma frequencies (18–26 Hz). MEG recording before/after 3-month

intervention. Increased beta power in several cortical regions post-intervention. Parent-reported behavioral improvements in social interaction and stereotypies.

Critical Finding: *First (albeit small) study attempting to normalize specific frequency band alterations in autism via external stimulation.*

8. THEORETICAL FRAMEWORKS

8.1 Hardy & LaGasse (2013) — Rhythmic Rehabilitation Model

Journal: Frontiers in Integrative Neuroscience

DOI: <https://doi.org/10.3389/fnint.2013.00019>

Title: "Rhythm, movement, and autism: Using rhythmic rehabilitation research as a model for autism"

Theoretical framework paper proposing that rhythmic rehabilitation research (stroke, Parkinson's, TBI) provides model for autism intervention. Core premise: external rhythm (metronome, music) can scaffold disrupted internal timing systems. Reviews evidence for Rhythmic Auditory Stimulation (RAS) improving gait, motor coordination, and speech production in neurological conditions. Proposes applying same principles to autism given similar timing/motor difficulties. Mechanisms: auditory-motor coupling, entrainment of motor planning circuits, predictive timing enhancement. Emphasizes rhythm as scaffold, not cure.

Critical Finding: *Established theoretical foundation for rhythm-based autism interventions, drawing on rehabilitation neuroscience evidence.*

8.2 LaGasse et al. (2024) — Updated Sensorimotor Organization Framework

Journal: Frontiers in Integrative Neuroscience

DOI: <https://doi.org/10.3389/fnint.2024.1403876>

Title: "Rhythm and music for promoting sensorimotor organization in autism"

Recent (2024) perspective on music and rhythm-based interventions in autism. Key premise: many autistic individuals have music processing and production abilities similar to neurotypical peers—individual strengths that can be leveraged in competence-based treatment. Updated perspective on mechanism: rhythm/music promotes sensory and motor regulation → impacts motor, social, and communicative skills. Music engages and motivates, can be used intentionally for skill acquisition. Positions rhythm and music as valuable tools for skill development in autism spectrum. Note: Hardy is co-author on both this 2024 paper and the 2013 paper—11 years of sustained research.

Critical Finding: *Competence-based, strength-focused update to foundational rhythmic rehabilitation model—11-year sustained research perspective.*

8.3 Bharathi et al. (2019) — Rhythmic Entrainment Framework

Journal: Journal of Exercise Rehabilitation

DOI: <https://doi.org/10.12965/jer.1836578.289>

Title: "Rhythmic entrainment framework for autism interventions"

Theoretical framework proposing rhythmic entrainment as organizing principle for autism interventions. Provides conceptual model for how external rhythm supports internal regulation.

Critical Finding: *Framework paper establishing theoretical foundation for entrainment-based intervention design.*

8.4 Amos (2013) — Parent/Researcher Perspective

Journal: Frontiers in Integrative Neuroscience

DOI: <https://doi.org/10.3389/fnint.2013.00027>

Title: "Learning to dance: comprehensive perspective on autism and rhythm"

Comprehensive perspective integrating parent and researcher viewpoints on rhythm and autism. Provides integrated view of rhythm as both clinical tool and lived experience.

Critical Finding: *Framework paper with unique parent/researcher dual perspective—bridges clinical and community understanding.*

9. MULTI-SYSTEM RHYTHM DYSREGULATION

9.1 Cheung et al. (2016) — Biomusic

Journal: Frontiers in Neuroscience

DOI: <https://doi.org/10.3389/fnins.2016.00401>

Title: "Biomusic: An Auditory Interface for Detecting Physiological Indicators of Anxiety"

"Biomusic" auditory interface for detecting physiological indicators of anxiety. Participants: typically developing children (n=10) + children with ASD (n=5). Maps physiological signals to music: electrodermal activity → melody, skin temperature → musical key, heart rate → drum beat, respiration → "whooshing" embellishment. Adult listeners (n=16) classified "anxious" vs "relaxed" states from Biomusic samples. Results: 80.8% classification accuracy (sensitivity 84.9%, specificity 76.8%). Early accurate impression within 12.1 seconds, minimal training (<10 min).

Critical Finding: *Rhythm (heart rate, respiration) mapped to auditory features for intuitive physiological state detection—links autonomic rhythms to perceptible auditory rhythms.*

9.2 Ming et al. (2016) — Respiratory and Autonomic Dysfunction

Journal: Brain and Development

DOI: <https://doi.org/10.1016/j.braindev.2015.07.003>

Title: "Respiratory and autonomic dysfunction in children with autism spectrum disorders"

Study examining respiratory patterns and autonomic nervous system function in children with ASD (n=56) vs neurotypical controls (n=56), ages 4–11. ASD group showed irregular breathing patterns (increased breath-to-breath variability), reduced HRV and RSA (indicating reduced parasympathetic/vagal tone), and altered autonomic balance (increased sympathetic relative to parasympathetic). Breathing irregularity correlated with autism symptom severity. Conclusions: autonomic dysregulation and respiratory rhythm disruption are features of ASD, may contribute to anxiety, sleep problems, and behavioral regulation difficulties.

Critical Finding: *Direct evidence for multi-system rhythm dysregulation—neural, respiratory, cardiac rhythms all affected. Links internal rhythm disruption to physiological regulation challenges.*

10. NEURODIVERSITY-AFFIRMING PERSPECTIVES

Several papers in this reference guide take explicitly neurodiversity-affirming stances. This section highlights the key ones for clinical and community use contexts.

See Christensen (2021) — Section 4.3 — Cultural/anthropological perspective using syncopation concept as non-pathological framework for temporal differences in autism.

See LaGasse et al. (2024) — Section 9.2 — Competence-based treatment approach emphasizing autistic individuals' musical strengths over deficit framing.

See Navarro et al. (2025) — Section 6.1 — Meta-analysis explicitly recommending "personalized, neurodiversity-affirming therapeutic models."

See Daniel et al. (2022) — Section 4.2 — Rhythmic Relating framework positioning social timing as bidirectional challenge, validating autistic timing as different but valid.

APPENDIX: QUICK REFERENCE BY FREQUENCY BAND

5–13 Hz Range (Alpha Band — The Drum Protocols' 7 Hz Target)

- Welsh 2005: 5–13 Hz inferior olive disruption
- Dickinson 2025: 6–9 Hz accelerated maturation
- Neo 2023: Reduced relative alpha (7–13 Hz)
- Ippolito 2022: Alpha (7–13 Hz) across disorders
- Strang 2022: Slowed peak mu (8–12 Hz)
- Kawasaki 2017: Frontal theta 6 Hz during synchronization

3–6 Hz Range (Theta Band)

- Jones 2020: Theta (3–6 Hz) predicts intelligence
- Fan 2023: Rhythmic sampling (4–8 Hz theta)
- Taweeseedt 2025: Theta at sleep onset
- Buzzell 2022: Late mediofrontal theta deficits

Theta-Burst Interventions

- Jannati 2020, 2021: Continuous theta-burst stimulation
- Blank 2025: Accelerated theta burst for depression
- Kaokhieo 2023: 5-Hz rTMS

Gamma Band

- Neo 2023: Increased gamma (large effect $g=1.06$)
- Anninos 2019: Beta-gamma (18–26 Hz) intervention

Convergence on The Drum Protocols' 7 Hz Target

Independent evidence from five research groups spanning 20 years:

- Welsh (2005): Identified 5–13 Hz disruption range
- Dickinson (2025): Documented 6–9 Hz alterations
- Neo (2023): Confirmed reduced 7–13 Hz alpha
- Kawasaki (2017): Found 6 Hz theta elevation during synchronization
- The Drum Protocols: Independently chose 7 Hz

7 Hz falls precisely in the MIDDLE of:

- Welsh's 5–13 Hz inferior olive disruption range
- Dickinson's critical 6–9 Hz maturation band
- Neo's 7–13 Hz reduced alpha range
- The theta-alpha boundary where multiple studies show alterations

USAGE NOTES

For Researchers

- DOI links allow direct access via institutional subscriptions
- Abstracts provide quick assessment of relevance
- Organized by topic for literature review efficiency

For Clinicians

- Topic organization facilitates finding intervention evidence
- RCT section provides highest-quality evidence for practice
- Null findings section ensures balanced perspective

For Developers

- Foundational neuroscience section explains mechanism
- Intervention studies demonstrate feasibility
- Biomarker section suggests outcome measures

For Educators

- Theoretical frameworks section provides conceptual foundation
- Neurodiversity section offers affirming language
- Multi-system section shows breadth of impact

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Research Access: <https://bit.ly/the-drum-protocols-research>

Date: February 2026 · Purpose: Scientific foundation for The Drum Protocols therapeutic rhythm system

END OF REFERENCE GUIDE