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Review Article

Vibroacoustic, Rhythmic and 40 Hz Sensory Stimulation in Neurological Conditions: A Narrative Review of the Evidence and Research Gaps

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Abstract

Background: Sound acts on the nervous system as a physical stimulus as well as a subjective experience. Vibroacoustic therapy (VAT), rhythmic sensory stimulation (RSS) and 40 Hz gamma sensory stimulation use defined acoustic or vibrotactile parameters but are usually reviewed separately.

Methods: This narrative review draws on systematic, scoping and Cochrane reviews, key randomised trials and mechanistic studies. Each source was checked against the claims made.

Findings: Rhythmic auditory cueing has the most mature evidence, with moderate-certainty gains in gait velocity and stride length after stroke and meta-analytic support for gait and motor improvement in Parkinson's disease. VAT, usually delivered at 40 Hz, shows promising but low-certainty results in Parkinson's disease, cerebral palsy, pain and dementia; studies are small, shams are weak and stimulus parameters are poorly reported. Combined 40 Hz light and sound stimulation have a strong animal rationale, contested replication, acceptable human safety and mixed efficacy signals, with a pivotal trial pending. Tactile 40 Hz stimulation has reduced neurodegenerative pathology in mice but has not been tested with neural measures in humans.

Gaps: No study has derived vibrotactile stimuli from the structure of music and compared them with matched sine-wave vibration. Frequency and dose comparisons are largely absent, stimulation is rarely personalised, human neural entrainment by vibration is unverified, and shams, reporting and independent replication are weak.

Conclusion: The evidence supports careful, mechanism-first research into music-derived, individually tailored vibroacoustic stimulation, beginning with calibrated studies in healthy volunteers that combine EEG and physiological measures with credible control conditions.

Keywords: Vibroacoustic therapy, Rhythmic auditory stimulation, Rhythmic sensory stimulation, Gamma entrainment, 40 Hz Stimulation, Vibrotactile stimulation, Music therapy, Neurorehabilitation

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Introduction

Music therapy has traditionally been organised around the listener's subjective experience: preference, emotion, memory and meaning. This approach has produced real benefits, but it makes stimuli difficult to standardise. Two patients with the same neurological condition may receive quite different music, and the active ingredient is hard to isolate.

A parallel tradition treats sound as a physical stimulus with measurable parameters such as frequency, rhythm, amplitude and modulation. Three lines of work belong to this tradition. Vibroacoustic therapy delivers low-frequency sound as vibration through the body [1]. Rhythmic sensory stimulation uses periodic auditory or tactile input, either to cue movement or to entrain neural rhythms [2-4]. Gamma sensory stimulation at 40 Hz uses flicker, tones or vibration with the aim of engaging gamma-band brain activity and, in animal models, modifying neurodegenerative pathology [5-7].

These literatures are usually reviewed separately. Considering them together matters for a specific research question: whether the structure of music, including its melody, rhythm and dynamics, can be translated into defined vibrotactile and acoustic parameters, prescribed to an individual, and tested for positive or negative effects on neurological function.

This review addresses three questions:

1. What has been tested with vibroacoustic therapy, rhythmic sensory stimulation and 40 Hz sensory stimulation, in which conditions, and with what designs?
2. What do the findings suggest about benefit, harm and mechanism?
3. Which gaps must be addressed before music-derived, individually tailored vibration can be evaluated clinically?

Methods

This is a narrative review that prioritises existing systematic, scoping and Cochrane reviews, supplemented by key primary trials and mechanistic studies. It is not a systematic review, and no formal risk-of-bias assessment or meta-analysis was undertaken.

Sources: PubMed and PubMed Central, publisher platforms (Frontiers, MDPI, PLOS, BMJ and the Cochrane Library), medRxiv, trial registries and conference reports were searched from inception to October 2026.

Search terms: Searches combined the terms vibroacoustic therapy, physioacoustic, sound vibration, low-frequency sound stimulation, rhythmic sensory stimulation, rhythmic auditory stimulation, rhythmic cueing, vibrotactile cueing, gamma entrainment, 40 Hz, GENUS and sensory stimulation with condition terms (Parkinson's disease, stroke, cerebral palsy, Alzheimer's disease, dementia, fibromyalgia and pain).

Selection: The review included (a) systematic, scoping and Cochrane reviews of each modality; (b) randomised or controlled trials in neurological or pain populations not already well summarised by a review; (c) foundational animal studies of 40 Hz stimulation and direct attempts to replicate them; and (d) technical sources on vibrotactile perception

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and the translation of music into vibration that bear on the gaps identified. Each cited source was read and checked against the claims made.

Limitations: Selection was not exhaustive and was not duplicated independently, only English-language publications were searched, and one major trial report is a preprint that has not been peer reviewed [8]. The findings should therefore be read as a structured overview and a foundation for a future registered scoping review, not as a quantitative synthesis.

Vibroacoustic Therapy

Definition and origins

Vibroacoustic therapy (VAT) delivers low-frequency sinusoidal sound through transducers built into a bed, chair or mat, so that the body receives the sound as vibration. Its origins lie with the Norwegian educator and therapist Olav Skille, who defined VAT as the therapeutic use of sinusoidal low-frequency sound in the range of 30 to 120 Hz, complemented by music [1]. A related physio acoustic method, developed by Lehikoinen in the 1990s, uses frequencies of 27 to 113 Hz [1]. Commercial systems include the Next Wave physio acoustic chair, the Somatron, the Music Vibration Table and several vibroacoustic beds [1,9].

VAT should be distinguished from whole-body vibration (WBV), which uses mechanical platforms rather than loudspeaker-driven sound, and from purely auditory music therapy. Recent reviews separate sound vibration from mechanical vibration when synthesising results [10].

Proposed mechanisms

The mechanisms of VAT remain under debate [1]. Proposals include stimulation of mechanoreceptors in the skin and deeper tissues with downstream effects on somatosensory and motor pathways, modulation of muscle tone through spinal reflex circuits and, for 40 Hz protocols, a hypothesised link with thalamocortical gamma rhythms. The frequencies used in early VAT rest largely on clinical experience rather than on dose-response data [1]. Receptor physiology is also relevant to stimulus design. Computational modelling places the peak sensitivity of the human Pacinian corpuscle at around 130 to 170 Hz [11], higher than most VAT protocols use, so stimulation at 30 to 60 Hz may engage different mechanoreceptor populations from those most sensitive to vibration.

Evidence by condition

Cerebral palsy: An advanced narrative review identified seven relevant studies, two randomised controlled trials (RCTs) and five pre-post designs, most of them small, involving children aged 1 to 8 years and adults aged 24 to 77 years [1]. All seven reported improved motor function, six with statistical significance, and three paediatric studies reported reduced muscle tone. Frequencies ranged from a single 40 Hz tone to a sweep from 16 to 150 Hz. The authors concluded that VAT “could potentially improve motor function” but noted the absence of blinded trials, of data on adolescents and of any comparison between frequencies [1].

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Pain: A scoping review of VAT in adults with pain included 20 studies, most concerning fibromyalgia and other chronic pain, of which three were RCTs [9]. The most common frequency was 40 Hz, and sessions typically lasted 20 to 45 minutes. Results from the RCTs were mixed: one showed significant relief, one found no difference between groups, and a crossover RCT found VAT no better than self-selected music. The review concluded that research is "too sparse to identify properties of VAT that are beneficial for pain management" [9].

Dementia: A scoping review of tactile low-frequency vibration in dementia identified eight studies published between 1993 and 2019, three of them RCTs; five used sound vibration, typically at 40 Hz, and three used mechanical vibration [10]. Reported benefits included greater engagement and alertness, reduced use of as-needed medication in one nursing-home study, and EEG and cognitive changes in one WBV study. Methodological quality varied, blinding was rarely achieved, and stimulus parameters were often reported too poorly to allow replication [10].

Parkinson's disease: The strongest single trial is a double-blind, placebo-controlled RCT of 40 Hz physio acoustic stimulation delivered in 25-minute sessions three times a week for 12 weeks [12]. Of 47 participants recruited, 36 had complete data. Scores on Part III of the Unified Parkinson's Disease Rating Scale (UPDRS-III) improved in the active group ($p < 0.001$) but not in the placebo group ($p = 0.16$), with gains in rigidity, finger tapping and postural stability; gait did not improve. Limitations include attrition, multiple uncorrected comparisons, post hoc responder analyses and a placebo condition that relied on telling participants the vibration might not be felt [12].

Summary

VAT has a long clinical history and a generally favourable safety record, but its evidence base is small, heterogeneous and rarely blinded. Three weaknesses recur across reviews: inadequate reporting of frequency, amplitude and dose; a lack of credible sham conditions; and no systematic comparison of frequencies or stimulus types [1,9,10].

Rhythmic Sensory Stimulation and Rhythmic Cueing

The term rhythmic sensory stimulation (RSS) is used in two related senses. In movement rehabilitation, it refers to rhythmic auditory stimulation (RAS), or cueing, in which a metronome or rhythm-enhanced music sets the timing of walking or arm movement. In the vibroacoustic literature, it refers to periodic sound or vibration at a fixed frequency, usually in the gamma range, intended to entrain neural activity [2,3]. Both traditions rest on the idea that a regular external rhythm can organise neural timing, but they operate on different time scales. Movement cueing works at roughly 1 to 2 Hz, the rate of stepping, whereas entrainment protocols work at tens of hertz.

Rhythmic auditory stimulation for gait

Stroke: A Cochrane review of music interventions for acquired brain injury (29 trials, 775 participants) found that RAS increased gait velocity by 11.34 m/min (95% CI [8.40, 14.28]; 9 trials, 268 participants; moderate-certainty evidence) and stride length on the affected side by 0.12 m (95% CI [0.04, 0.20]; moderate certainty; [4]. Cadence also improved, with low certainty. Overall research quality was low, only one study was at low risk of bias, and no harms were reported [4].

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Parkinson's disease: A meta-analysis of randomised trials found that RAS improved step length, stride length, UPDRS-III scores (mean reduction of 1.59 points), Timed Up and Go performance and Berg Balance Scale scores, but not cadence [13]. Heterogeneity was high for several gait outcomes, participants and trainers were usually not blinded, cue tempo was not standardised across trials, and only two studies reported follow-up [13].

Vibrotactile cueing

Rhythmic cues can also be delivered as vibration, which is discreet and unaffected by ambient noise. A technological review of wearable cueing devices for freezing of gait found mixed results for auditory and visual cueing, with some studies showing benefit, some none and one worsening, and very few vibrotactile studies reporting outcome data [14]. Samples were small (7 to 30 participants), exposure was brief and home use was rarely tested objectively [14]. Whether vibrotactile cues match or exceed auditory cues for gait remains largely untested.

Gamma-frequency stimulation in pain and cognition

Fibromyalgia: In a double-blind parallel RCT, 50 patients received 30-minute vibrotactile sessions five days a week for five weeks, comparing a continuous 40 Hz sine wave with random, intermittent, complex gamma-range stimulation [3]. Both groups improved in symptom severity, pain interference, depression and sleep quality, but the groups did not differ and there was no control condition without stimulation. The trial therefore cannot separate a frequency-specific effect from the non-specific effects of attending sessions [3].

Alzheimer's disease: An exploratory crossover pilot gave 18 people with mild, moderate or severe Alzheimer's disease six sessions of 40 Hz sound stimulation and six sessions of a visual (DVD) control [2]. Cognitive scores on the Saint Louis University Mental Status examination showed significant positive slopes during 40 Hz stimulation but not during the control condition, with the clearest effect in mild and moderate disease. The authors emphasised the small sample and exploratory design [2], and a later scoping review noted that the apparent decline in benefit with greater severity was not statistically significant [10].

Summary

Rhythmic cueing for gait is the most mature application of rhythm in neurorehabilitation, with moderate-certainty evidence after stroke and supportive meta-analytic evidence in Parkinson's disease [4,13]. Gamma-frequency RSS is at an earlier stage: trials are small, and the only double-blind RCT compared two active stimuli without a sham [3]. In both traditions, cue parameters are rarely personalised beyond matching the tempo to walking cadence.

Gamma Sensory Stimulation at 40 Hz

Animal studies

Current interest in 40 Hz stimulation began with Iaccarino et al. [5], who found that driving fast-spiking interneurons at 40 Hz reduced amyloid-β in a mouse model of Alzheimer's disease and that non-invasive 40 Hz light flicker reduced amyloid in the visual cortex. Martorell et al. [6] extended this approach, known as gamma entrainment using sensory

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stimuli (GENUS), to sound. Seven days of 40 Hz auditory tones improved spatial and recognition memory and reduced amyloid in the auditory cortex and hippocampus, and combined auditory and visual stimulation produced wider effects, including in the prefrontal cortex. Murdock et al. [15] proposed a mechanism in which multisensory 40 Hz stimulation increased glymphatic clearance, arterial pulsatility and astrocytic aquaporin-4 polarisation through a process dependent on vasoactive intestinal peptide interneurons.

Of direct relevance to vibration, Suk et al. [7] delivered whole-body 40 Hz vibrotactile stimulation to two mouse models of neurodegeneration for 1 hour a day. They reported fewer cells positive for phosphorylated tau in the somatosensory cortex, preserved neuron counts, fewer markers of DNA damage and better motor performance on rotarod and grid-hang tests. The authors acknowledged small samples and did not test other frequencies.

These animal findings are contested. Soula et al. [16] reported that 40 Hz light did not entrain native hippocampal gamma oscillations or significantly reduce amyloid in a mouse model of Alzheimer's disease, prompting debate about methodological differences and the need for independent replication.

Human studies

Feasibility and pilot data: Chan et al. [17] showed that brief 40 Hz light and sound stimulation increased scalp EEG power at 40 Hz in healthy younger and older adults and in people with mild Alzheimer's disease, with intracranial evidence of entrainment in the hippocampus and amygdala in two patients with epilepsy and no epileptiform activity. In a 3-month randomised pilot (n=15), daily 1-hour stimulation at home was associated with less ventricular enlargement and preserved functional connectivity compared with control, but standard cognitive scales did not differ [17].

Overture: In a sham-controlled, double-blind multicentre trial in which 76 participants were randomised to 6 months of daily 1-hour stimulation, 40 Hz audiovisual stimulation was well tolerated, and no amyloid-related imaging abnormalities were reported [8]. The prespecified efficacy measures (ADAS-Cog14, CDR-SB and a composite score) did not differ between arms, whereas secondary measures (ADCS-ADL and MMSE) and whole-brain volume favoured active stimulation. Tinnitus (15% vs. 0%) and headache (22% vs. 11%) were more common with active stimulation. The report is a preprint that has not been peer reviewed, the trial was sponsored by the device manufacturer, and about 28% of participants withdrew [8].

Pivotal trial: The HOPE pivotal study enrolled about 670 adults with mild to moderate Alzheimer's disease for daily home-based 40 Hz light and sound stimulation compared with sham, with topline results expected around mid-2026 [18,19]. Peer-reviewed results were not available at the time of writing.

Vibration at 40 Hz in humans: Human studies of 40 Hz vibration, as distinct from light and sound, come mainly from the vibroacoustic literature reviewed in Sections 3 and 4: the Parkinson's disease RCT [12], the fibromyalgia RCT [3] and small studies in dementia [2,10]. None of these measured gamma entrainment directly with EEG during vibration.

Summary

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Of the three modalities, 40 Hz stimulation has the strongest mechanistic rationale, an encouraging early safety record in humans and a large pivotal trial pending. Its central uncertainties are whether the animal findings replicate [16], whether sensory-evoked 40 Hz activity in humans translates into clinical benefit [8,17], and whether tactile delivery engages the same mechanisms as light and sound, which no human study has yet shown.

Evidence Map

(Table 1) summarises what has been tested, by modality and condition. The column headed "Strongest design identified" records the highest-level study found in this review and is not a formal GRADE rating.

Modality	Condition	Typical parameters	Strongest design identified	Direction of findings	Key limitations
Rhythmic auditory cueing	Stroke gait	Metronome or rhythm-enhanced music at walking cadence	Cochrane meta-analysis (Magee et al., 2017)	Faster gait and longer stride (moderate certainty)	Mostly high risk of bias
Rhythmic auditory cueing	Parkinson's disease, gait and motor	Beats matched to cadence	Meta-analysis of RCTs (Wang et al., 2022)	Better step length, UPDRS-III and balance; cadence unchanged	Unblinded, high heterogeneity, little follow-up
Vibrotactile cueing	Parkinson's disease, freezing of gait	Pulsed vibration at step rate	Technology review of small studies (Sweeney et al., 2019)	Too little outcome data to judge	Very small samples, brief exposure
Vibroacoustic, 40 Hz	Parkinson's disease, motor	40 Hz chair, 25 min, 3 times weekly for 12 weeks	Double-blind RCT, 36 analysed (Mosabbir et al., 2020)	UPDRS-III improved; gait unchanged	Attrition, multiple comparisons
Vibroacoustic, 30 to 120 Hz	Cerebral palsy	40 to 60 Hz via beds or tables	Two small RCTs within a narrative review (Kantor et al., 2019)	Improved motor function and tone	No blinding, no frequency comparison
Vibroacoustic, mostly 40 Hz	Chronic and acute pain	Sessions of 20 to 45 min	Scoping review including 3 RCTs (Kantor et al., 2022)	Mixed; RCTs inconsistent	Heterogeneous protocols, no true sham
Vibrotactile gamma RSS	Fibromyalgia	40 Hz vs. complex gamma, 30 min, 5 days	Double-blind RCT, n = 50 (Janzen et al., 2019)	Both arms improved; no difference between them	No inactive control

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Modality	Condition	Typical parameters	Strongest design identified	Direction of findings	Key limitations
		weekly for 5 weeks			
Sound vibration, 40 Hz	Alzheimer's disease and dementia	40 Hz chair, twice weekly	Pilot crossover, n = 18 (Clements-Cortes et al., 2016); scoping review (Campbell et al., 2022)	Improved cognition and engagement in small studies	Small, rarely blinded, poorly reported
40 Hz light and sound	Alzheimer's disease	1 h daily at home for 3 to 6 months	Sham-controlled RCT, n = 76, preprint (Hajós et al., 2023)	Safe; function and brain volume favoured active; primary cognitive measures null	Sponsor-run, 28% dropout; pivotal trial pending
40 Hz vibrotactile	Neurodegeneration in mice	Whole-body 40 Hz, 1 h daily	Animal study (Suk et al., 2023)	Less tau pathology, better motor function	Not yet tested in humans with EEG
Music-derived, individually tailored vibration	Any neurological condition	Not applicable	None identified	Not applicable	Untested

Table 1. Evidence Map of Vibroacoustic, Rhythmic and 40 Hz Sensory Stimulation

Note: RCT=Randomised Controlled Trial; RSS=Rhythmic Sensory Stimulation; UPDRS-III=Unified Parkinson's Disease Rating Scale, Part III.

A clear pattern emerges. Fixed-frequency stimulation, almost always at 40 Hz, and fixed-tempo cueing dominate the literature. Stimuli are rarely derived from the structure of music, parameters are rarely tailored to the individual, and no study has compared music-derived vibration with plain sine-wave vibration.

Gaps and Research Priorities

Gap 1: No dose-response or frequency-comparison data: VAT frequencies rest largely on clinical tradition [1], and reviews repeatedly note that frequencies and waveforms have not been compared directly [1,9]. The one direct comparison of two gamma waveforms found no difference but lacked an inactive arm [3]. Priority: systematic within-subject comparison of frequencies, waveforms and intensities, with neural and clinical outcomes.

Gap 2: Stimuli are rarely derived from music: Despite the name of the field, most protocols deliver a pure sinusoid, with music played separately or not at all [1,3,9,10,12]. Translation of music into touch exists in accessibility technology; the Emoti-Chair, for example, divides music into eight frequency bands mapped to 16 voice coils [20], but this approach has not been tested therapeutically. Priority: define a reproducible transformation of melody, rhythm

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and loudness into vibrotactile parameters, and test whether music-derived vibration differs from matched sine-wave vibration.

Gap 3: Parameters are not personalised: Apart from matching cue tempo to walking cadence in gait studies [4,13], stimulation is applied uniformly. Closed-loop acoustic stimulation tuned to each person's EEG rhythm is now technically feasible [21] but has not been combined with vibrotactile or music-derived stimuli. Priority: develop and test individual sound prescriptions based on neural or physiological profiles.

Gap 4: Mechanisms of tactile delivery are unverified in humans: Evidence of 40 Hz entrainment in humans comes from light and sound [8,17], and effects of tactile 40 Hz stimulation on brain pathology have been shown only in mice [7]. No human study in this review recorded EEG entrainment during vibroacoustic stimulation. Priority: concurrent EEG during vibration, with appropriate control of artefact.

Gap 5: Weak control conditions and blinding: Shams that rely on telling participants the vibration may not be felt [12], and comparisons between two active conditions [3], leave expectation effects unresolved. Reviewers note that no fully adequate sham for perceptible vibration exists [9,10]. Priority: multi-arm designs that include audio-only, sine-wave and sub-threshold sham conditions, with formal checks of blinding.

Gap 6: Poor reporting: Frequency, amplitude, waveform, contact area, device and dose are reported inconsistently, which prevents replication [9,10], and delivered vibration is rarely measured with accelerometers. Priority: adopt a minimum reporting standard and calibrate delivered acceleration.

Gap 7: Limited evidence in neurorehabilitation beyond gait: Outside gait cueing in stroke and Parkinson's disease, rehabilitation populations such as people with acquired brain injury, spasticity or post-stroke pain have few controlled vibroacoustic trials. Priority: pilot trials in these populations once safety and mechanistic work in healthy volunteers is complete.

Gap 8: Replication and independence: Influential 40 Hz findings are disputed in animals [16], and the main human trials are sponsored by device developers [8,18]. Priority: independent, pre-registered replication with open data and publication of null results.

Conclusion

Across three overlapping literatures, the clearest message is that rhythm and low-frequency vibration can produce measurable effects on movement and possibly on brain function, but the field has not yet established which properties of the stimulus matter or for whom. Rhythmic auditory cueing for gait has the firmest evidence. Vibroacoustic therapy and gamma-frequency stimulation are promising but underpowered, insufficiently blinded and poorly reported, and the 40 Hz animal literature requires independent replication.

The most distinctive open question is whether music can be decomposed into defined vibrotactile and acoustic parameters, and whether such music-derived stimuli, tailored to an individual's neural profile, outperform generic sine-wave vibration. Answering it will require a reproducible transformation algorithm, calibrated delivery, concurrent

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EEG and physiological measurement, and multi-arm designs with credible controls. A Phase 1 study in healthy volunteers built on these principles is the appropriate next step before clinical trials in neurological populations.

Declarations

Author contributions: VB conceived the review, conducted the literature search, interpreted the evidence, and wrote and approved the final manuscript.

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Competing interests: VB is the founder and a director of Music Research Centre Australia Pty Ltd, which conducts research on music-derived vibroacoustic stimulation, and is a composer holding music publishing rights through APRA AMCOS. VB has no financial interest in any device or company discussed in this review.

Ethics approval: Not applicable; this is a review of published literature.

Data availability: No new data were generated. All sources are cited.

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