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Vagus Nerve and Vagus Nerve Stimulation – Its Role in Chronic Disorders and Therapy Including Impact of Sound

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ABSTRACT

The vagus nerve (VN) is a major component of the parasympathetic nervous system and serves as a bidirectional communication pathway between the brain and visceral organs. It plays an important role in regulating cardiovascular, respiratory, gastrointestinal, endocrine, immune, and inflammatory functions. Chronic diseases are frequently associated with reduced vagal activity, impaired autonomic balance, and increased sympathetic dominance, contributing to inflammation and allostatic stress. Vagus nerve stimulation (VNS) has emerged as a promising neuromodulatory approach for restoring autonomic and neuroimmune balance. While conventional VNS uses implantable devices, non-invasive approaches, particularly transcutaneous auricular vagus nerve stimulation (taVNS), target the auricular branch of the vagus nerve and may provide a safer and more accessible therapeutic option. Emerging evidence also suggests that sound and music may influence autonomic regulation and potentially complement vagal stimulation. This review discusses the anatomy and physiological functions of the vagus nerve, its role in neuroimmune and homeostatic regulation, VNS and taVNS approaches, and the potential relevance of Polyvagal Theory in understanding brain–body communication and chronic disease management.

Keywords: Vagal nerve; Stimulation; Microcurrent; Music sound toning; Chronic disorders

INTRODUCTION

The vagus nerve, being the main parasympathetic conduit, a key communication highway between brain and body, regulates heart rate, gut motility, respiration, endocrine responses, and immune tone—essentially shaping the "set point" of autonomic balance.[1] Chronic illnesses across cardiovascular, metabolic, inflammatory, and psychiatric domains often show a characteristic pattern: reduced vagal activity (low heart rate variability) and relative sympathetic dominance, which amplifies inflammation, endothelial stress, and allostatic load.[2] Vagus Nerve has neuroimmune and homeostatic effects and ameliorates the sympathovagal imbalance in most chronic disorders.

Vagus nerve stimulation (VNS) is a neuromodulation therapy that involves delivering mild electrical pulses to the vagus nerve. Vagal Nerve Stimulation can ameliorate many disorders and can be done through implantable devices in the cervical region, but more importantly, through transcutaneous route, using devices that utilize microcurrent (direct current -DC).[1,3,4] Surprisingly, sound and music have healing effects,[5] and this can be enacted through Transcutaneous auricular VNS (taVNS), which targets the auricular branch of the vagus nerve at the ear (cymba conchae, tragus), using non-invasive surface electrodes.

WHAT IS THE VAGUE NERVE?

The vagus nerve is a major component of the autonomic nervous system that connects the brainstem with organs in the body. It contributes to regulation of heart rate, breathing, digestion, and aspects of social behavior, as part of **integrated autonomic circuits**. It arises from the medulla oblongata as a series of rootlets along the post olivary sulcus. These rootlets converge and exit the cranium via the jugular foramen. The VN descends vertically within the carotid sheath in the neck, along its cervical course, it gives rise to several key branches. The auricular branch provides sensory innervation to the external auditory canal and portions of the auricle.[6]

The pharyngeal branches contribute to the pharyngeal plexus, which also receives fibers from the glossopharyngeal nerve and the superior cervical sympathetic ganglia.[7] Its route downline innervates all major thoracis and abdominal organs (Figure 1)

Vagus nerve is a "super highway" in the body providing the primary arm of the parasympathetic nervous system, connecting the "three brains" of the body – heart, gut and brain. (The vagus nerve also feeds back interoceptive information to brainstem and limbic structures. This bidirectional loop allows the CNS to continuously tune peripheral physiology. It thereby regulates neuroimmune, autonomic regulation and homeostasis. It impacts on cholinergic anti-inflammatory pathway, can suppress pro-inflammatory cytokine release (Figure 1 legend) central to rheumatic, metabolic, and postoperative inflammatory control. Finally, it mediates sympathovagal imbalance in chronic disease[1] (Figure 2). Restoring vagal tone is therefore not just "relaxation"—it is a mechanistic intervention on inflammatory and vascular trajectories.

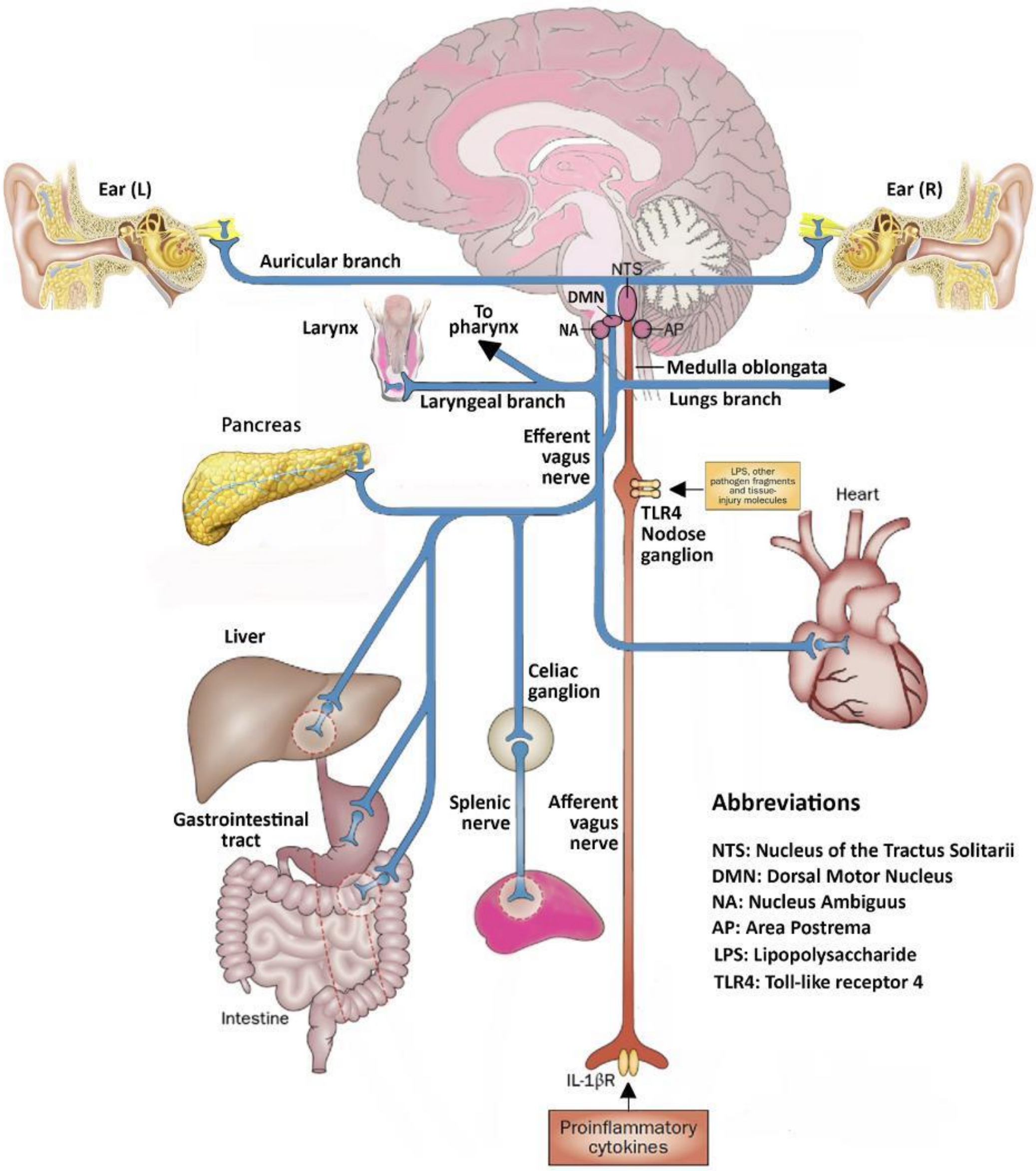

Figure 1 This compelling drawing of the human Vagus Nerve system has been substantially modified by John Stuart Reid of the Cymascope Foundation, with permission of Pavlov and Tracey, originators of a simplified version.[8] Inflammatory mediators, such as cytokines, are released by activated macrophages and other immune cells upon immune challenge, and are detected by sensory components of the afferent arm of the inflammatory reflex. Neural interconnections between the NTS, AP, DMN, NA and higher forebrain regions integrate afferent

(red) and efferent (blue) vagus output, thus, regulating immune activation, suppressing pro-inflammatory cytokines and reducing inflammation. Vagus efferent output can be supported by auricular and laryngeal input.

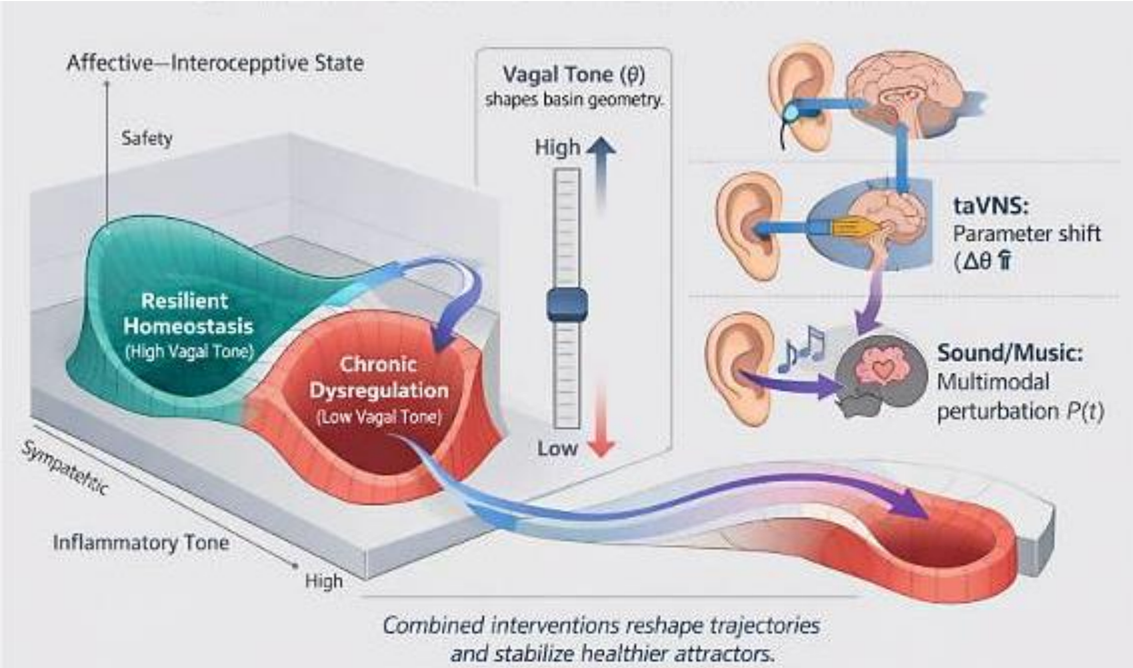

Figure 2 (AI generated). Vagal tone is a parameter for chronic disease. and its modulation by transcutaneous auricular vagus nerve stimulation (taVNS) and sound/music. The host system is represented as a multidimensional state space with axes corresponding to autonomic balance (sympathetic–parasympathetic ratio), inflammatory tone (baseline cytokine activity and cholinergic anti-inflammatory pathway efficacy), and affective–interoceptive state (limbic–prefrontal regulation and threat appraisal). Within this landscape, chronic illness corresponds to a maladaptive basin of attraction characterized by low vagal tone, sympathetic dominance, and persistent inflammation, whereas resilient health corresponds to a basin with high vagal tone, flexible autonomic responses, and lower inflammatory set points. Vagal tone is modeled not as a single variable but as a global parameter (θ) that shapes the geometry of these basins—their depth, width, and escape thresholds. Transcutaneous auricular vagus nerve stimulation (taVNS), delivered via the auricular branch of the vagus nerve, is conceptualized as a structured perturbation that increases θ, thereby deepening the healthy attractor and flattening the chronic illness attractor through coordinated modulation of nucleus tractus solitarius, autonomic output, and neuroimmune signaling. Sound and music, particularly when engaging respiration, affective circuits, and auricular somatosensory–vagal pathways, are modeled as continuous multimodal perturbations P(t) that smooth the landscape, reduce threat biased gradients, and bias trajectories toward safety-oriented states. Together, repeated taVNS and sound/music interventions can shift trajectories out of chronic illness basins and stabilize new, healthier attractors in the host–environment phase space.

WHAT IS POLYVAGAL THEORY?

This was developed by Stephen Porges [9] and is a scientific framework focused on autonomic regulation—how the autonomic nervous system continuously organizes physiological state in response to environmental demands. Rather than simply describing responses to stress, Polyvagal Theory explains how autonomic regulation shapes the body’s ongoing capacity to maintain stability, support health, and adapt to changing conditions.

This regulation operates as a dynamic feedback system, continuously integrating signals from the body, the brain, the environment, and social interactions. Through this ongoing exchange of information, the nervous system adjusts physiological state in ways that influence physiology, perception, behavior, social engagement and sound[10].

VAGUS NERVE STIMULATION (VNS) AND AMELIORATION OF CHRONIC ILLNESS

There are a host of chronic disorders that are favorably improved by VNS. These include:
Addictions[11]
Arrythmias and heart failure[12]
Cancer prognosis and outcome[13]

Inflammatory and auto-immune conditions[14,15]
Crohn's disease and GIT problems[16]
Diabetes Type 2[17]
Parkinsons Disease[18,19]
Mental health[20]

Mechanisms of action relevant to chronic illness[1,21-23]
Neuroimmune modulation: VNS can reduce circulating pro-inflammatory cytokines (e.g., TNF-α, IL-6), with clinical trials showing benefit in rheumatoid arthritis, inflammatory bowel disease, systemic lupus erythematosus, and postoperative systemic inflammation. **Autonomic rebalancing:** VNS increases heart rate variability and shifts autonomic balance toward parasympathetic dominance, which is associated with improved cardiovascular outcomes and reduced allostatic load. Mechanistically, afferent vagal activation alters brainstem and hypothalamic output, recalibrating sympathetic tone and HPA axis activity. **Central network effects:** Neuroimaging studies show VNS and taVNS modulate limbic and prefrontal regions (amygdala, anterior cingulate, insula), which are implicated in mood, pain, and interoception. This supports clinical improvements in depression, anxiety, PTSD, and chronic pain syndromes via both bottom-up interoceptive recalibration and top-down cognitive-affective changes. **Metabolic and postoperative applications:** Emerging work suggests taVNS can influence metabolic syndrome and postoperative inflammatory responses, likely via CAP and autonomic rebalancing, pointing to a broader role in chronic cardiometabolic illness.

VAGUS NERVE STIMULATIONS

This can be achieved through
Implanted cervical VNS: This approach is approved for epilepsy and treatment-resistant depression, with expanding evidence in obesity, stroke rehabilitation, rheumatoid arthritis, migraine, and cluster headache. These applications leverage both central neuromodulation (limbic, cortical circuits) and peripheral autonomic/immune effects.[24]

Transcutaneous VNS: This targets predominantly the auricular branch of the vagus nerve at the ear (e.g., cymba conchae, tragus) using surface electrodes. It offers a non-invasive route to engage vagal afferents, modulate brainstem nuclei (nucleus tractus solitarius, locus coeruleus), and downstream autonomic and immune pathways. These hubs coordinate autonomic output, immune modulation via the cholinergic anti-inflammatory pathway and affective regulation through projections to insula, amygdala, and prefrontal cortex. How does one stimulate the vagus nerve non-invasively? This is done through microcurrent devices.

There are several microcurrent devices reported in reviews[3,25-27] that can provide VNS, and also outline the mechanisms of action, highlighting its physiological mechanisms. Our own studies in this field,[28-37] using the Dolphin MPS device highlights its efficacy in various clinical settings of scar tissue healing, pain relief, impact on heart rate variability (HRV) and VNS. All report favorable outcomes. In a comparative review,10 of 13 electrical stimulation devices (microcurrent), showed limited evidence of clinical reduction of pain or improvement in function. It's important to note that the Dolphin MPS is truly microcurrent, (Direct current, <1mA) whereas others (e.g.TENS -showed a 1-point improvement in pain out of 10[25,38] are alternating current that impart high voltage or high voltage peaks, but 'averaged' out to be in the microcurrent range (Avazzia device). Most devices are not microcurrent. Electrical stimulation is NOT all the same. Frequency, waveform, current intensity and pulse characteristics matter, and different devices can produce very different clinical outcomes.

All these studies are highly suggestive of positive outcomes, may influence overall energy balance by modulating cellular metabolism and energy production. Its potential impact on the stress response, including cortisol levels and stress-related pathways, suggests a broader systemic effect. At the systemic level, they demonstrate utility in pain management, modulating pain perception through mechanisms like endorphin release and pain relief. Additionally, they exhibit anti-inflammatory effects, impacting systemic inflammation levels and potentially offering benefits for conditions associated with chronic inflammation.[39] A meta-analysis review of microcurrent therapy studies (including ours) highlights that this modality of treatment "is a potential, core nonpharmacologic treatment option in clinical care with minimal adverse events and should be further investigated".[38]

SOUND, MUSIC, TONING AND VNS – PHYSICAL AND METAPHYSICAL EFFECTS

This is a new field of scientific study, yet all ancient traditions recognized the healing effects of sound, music and toning. (Figure 3). These ancient civilizations, despite separation by vast distance and time, shared profound insights into sound harmony and creation. They recognized that sound has power, precedes form, vibration shapes creation, music alters consciousness, harmony restores balance, and tone connects humans to something greater than themselves. "Music has been an integral part of the human experience as long as humanity has been around. It's been intuitively felt to have healing properties, but now we are in a position to study the mechanisms and optimize music-based interventions". Alexander Pantelyat, M.D., director of the Center for Music & Medicine John Hopkins.

Figure 3 AI generated. Various ancient traditions going back thousands of years understood the healing value of sound and music, both at a physical level and spiritual- a bridge to achieving higher states of consciousness (Reproduced with kind permission of Anders Holte and Cacina Meadu - http://www.anders-holte.com)

How does modern science relate to this? It is increasingly recognized that sound heals. Music elicits multifactorial benefits in emotional, social, cognitive, and academic aspects of human life. Music is clinically proven to reduce stress and anxiety, and improve mood and self-expression, particularly after traumatic events. Studies have also demonstrated that music promotes parasympathetic autonomic systems, suppresses hyperactivation of stress responses, and boosts immune functions. However, its ability to promote brain plasticity and signaling are only beginning to be realized. Moreover, its employment as a therapy for the treatment of specific aspects of other neurological_disorders, including neurodevelopmental and neurodegenerative conditions and their comorbidities, is fast becoming an interesting field of research.[40-45]

In addition to providing compelling evidence of the perception of sound at the cell level, these studies[46,47] also challenge the traditional concept of sound perception by living beings, which is that it is mediated by receptive organs like the brain. It turns out that your cells respond to sounds, too. Recent research has shown that vagus nerve stimulation (VNS) paired with tones, sound or with rehabilitative training can help patients to achieve reductions in tinnitus perception or to expedite motor rehabilitation after suffering an ischemic stroke. The rationale behind this treatment is that VNS paired with sound can drive neural plasticity in a controlled and therapeutic direction. [48]. Sound/music that is audible can have dramatic impact on healing from inflammatory disorders, nitric oxide production and modulation of the gut-brain axis.[49-52] Sound below audible range (<20Hz) has profound healing effects perhaps through the vagus nerve.[53] Dr. John Stuart Reid is an acoustic- physics researcher who has studied sound through his cymascope has, introduced the concept of "vagal tone heterodyne stimulation therapy" that stimulates the body healing via beautiful music heard through high-quality headphones.[53] He aligns this with nature's healing secret: the ears act as parabolic dishes, collecting low frequency sounds from the environment that are direct coupled into the vagus nerve (asVPN) catalysing the body's healing response. The sound of waterfalls, white water rivers, psithurism (sound of wind through the trees), ocean waves, all contain extremely low frequencies that you cannot hear but are deeply healing.

The therapeutic power of the human voice is well known, but the mechanisms by which vocal sound can promote healing have received little attention in the scientific and medical communities. In his article,[53] John Stuart Reid, begins by describing the sound bubble model of sound, as distinct from sound wave model, and discusses the significance of the little-known physics fact that "sound gives birth to light". Due to the inelastic atomic collisions that are a fundamental aspect of sound production, this phenomenon leads to the intriguing hypothesis that our songs will, in the fullness of time, reach the stars in the form of modulated infrared energy. The article proceeds to distill, in accessible language, deep insights into the biological therapeutic mechanisms that underpin vocalizations, including vocal sound's ability to mediate chronic inflammation by vagus nerve stimulation. The article ends with a reference to the work of Professor Sergey Petoukhov, "the thought that we are actually singing form of genetic music, music that brings healing to all life".

Finally, ancient traditions also addressed the metaphysical/spiritual aspects that sound has (almost certainly mediated through the vagus nerve) that have an enormous impact on well-being. These aspects relate to negative emotions (like deep seated anger, guilt, grief) and beliefs (like rejection, fear of various types), which are deep-seated in the subconscious mind, and form the basis of many chronic disorders.

CONCLUSION

The vagus nerve is crucial to maintain health and well-being. It also ameliorates a wide range of chronic disorders. VNS and auditory Vagal neuromodulation has great implications for inflammatory disorders, cardiometabolic disease, chronic pain, psychiatric conditions, and post-antibiotic dysbiosis. Combined taVNS and sound-based interventions may offer a mechanistically grounded, non-pharmacologic strategy for restoring resilient homeostasis. There is a growing body of literature that shows Bioelectric medicine, with microcurrent stimulation, to have great potential in clinical care, with microcurrent stimulation at the intersection of technological innovation and the intricacies of the human body.[3]

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