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The Pacini System and HALF-MIS Treatment

*Subsonic Music,
Consciousness, and Health*

Abstract: *What is the role of subsonic and low-frequency vibration in consciousness, music, and health? This article draws on neurophysiological, evolutionary, and clinical perspectives to examine the Pacini system — the body's subsonic vibratory perceptual system — and its relation to consciousness studies, music perception, and health and well-being. The Pacini system, while commonly overlooked, is structurally and functionally interlinked with various sensory, emotion, and pain processing pathways, and thereby modulates brain function and overall conscious experience. It also plays a key role in music perception, music stimulation, and treatments that rely on these, due to its sensitivity to lower ranges of the auditory system, including mid to low bass ranges. This paper presents a novel music stimulation treatment called High Amplitude Low Frequency Music Impulse Stimulation (HALF-MIS). HALF-MIS purposefully activates the Pacini system via subsonic and low-frequency vibrations, while also incorporating specifically designed, composed, and produced music*

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that delivers an harmonic sonic experience. We will discuss results and potential mechanisms of action from case studies and ongoing clinical trials of HALF-MIS, which provide promising indications of its efficacy in reducing pain, depression, anxiety, and long COVID-19 symptoms.

1. Introduction

What is the role of subsonic and low-frequency vibrations in consciousness, music, and health? This exploratory article examines the Pacini system — the body's subsonic perceptual system — and its relation to consciousness studies, music perception, and health and well-being. We discuss preliminary studies of a novel music technology called *High Amplitude Low Frequency Music Impulse Stimulation* (HALF-MIS) — which purposefully activates the Pacini system — to explore the relationship between subsonic and low-frequency stimulation, musical experience, and mental and physical health outcomes. In theorizing these preliminary findings, we draw on neurophysiological, evolutionary, and clinical perspectives to investigate the impact of music — both sonic and subsonic — on the human brain, nervous system, and conscious experience. As such, this paper contributes to current interdisciplinary research at the nexus of consciousness studies, music, and health.

Music has been used by humans throughout all of known history, and in all cultures studied to date (Wallin, Merker and Brown, 2000; Rehfeld, Tindall and Belisle, 2021). Physically, music is nothing but a mixture of vibrational frequencies, so it remains enigmatic as to how music may evoke things like meaning, wisdom, and beauty in humans. Music experience is a complex embodied process — the endless variations of sensations, emotions, associations, and reminiscence that accompany music making and music listening often offer an easily induced alteration of bodily and conscious states (Palhares, Sas and Gonçalves, 2024; Keller, 2012). For example, the effects of music on mood, creativity, and mental and physical health are diverse and widespread and have been broadly investigated (Toader *et al.*, 2023; Vuust *et al.*, 2022; Molnar-Szakacs and Overy, 2006; Green *et al.*, 2008; Høffding, Nielsen and Laeng, 2024).

HALF-MIS, the new music technology and experimental treatment modality to be discussed in this paper, draws upon these and other effects of music on our brains, bodies, and conscious experiences. HALF-MIS leverages both sonic and subsonic music stimulation to

treat a variety of conditions including stroke, spinal cord injury, neurogenic pain, depression, anxiety, and long COVID-19. As both a treatment device and research tool, HALF-MIS, detailed below, explores both sonic and subsonic components of music and how they affect human brain function.

We start by discussing the research findings that prompted and guided the development of the HALF-MIS technology, including details about the Pacini system from both neurophysiological and evolutionary perspectives. We discuss the relations between the Pacini system and music perception; relations between the Pacini system, limbic system, and emotion processing; relations between the Pacini system, the autonomic nervous system, pain processing, and vagus nerve activity; the structural and functional relations among each of these; and how these have informed HALF-MIS development. We then briefly present details of the HALF-MIS technology and treatment modality before continuing on to discuss three clinical case studies as well as the preliminary results from ongoing randomized controlled trials with HALF-MIS. We end by outlining the hypothesized neurological and experiential mechanisms underlying HALF-MIS treatment, and suggest avenues for further research.

2. The Pacini System

2.1. *Neurophysiological perspectives on the Pacini system*

Our capacity to sense vibration is based on the system of Pacini corpuscles (Dominy, 2009; Verrillo, 2014). Pacini corpuscles are microscopic mechanoreceptor sense organs (0.1 mm) that are distributed throughout the skin, joints, and ligaments — and, as will become important later, richly in the internal organs. Each Pacini corpuscle encloses a single nerve fibre. Whenever a Pacini corpuscle is mechanically compressed — for example by vibrations in objects, air, or water — it generates an afferent nerve signal that is sent to the brain for processing. The vibrations that activate Pacini corpuscles range from 1 Hz to at least 300 Hz (Bolanowski and Zwislocki, 1984; Verrillo, 2014), which overlaps with the lowest ranges of the auditory system (20 Hz–20,000 Hz) and extends into the range of low bass tones and subsonic frequencies that fall below the auditory threshold. As such, the body's low-frequency and subsonic perceptual system is based on Pacini corpuscle activation.

The physiology of the individual Pacini corpuscle is well investigated, as are the nerve pathways that link individual corpuscles to the brain, and the brain's cortical representations of vibratory stimulation (Frakowiak *et al.*, 1997; Verrillo, 2014; Kim *et al.*, 2025). However, our sense of vibration arises from the aggregate activity of thousands of corpuscles sending afferent signals to the brain simultaneously — not just from single Pacini corpuscle activation — which results in a fine-grained pattern of action potentials propagated to many different parts of the brain for complex signal processing. Through mechanisms that remain largely unknown, complex signal processing of aggregate Pacini corpuscle activation is brought to conscious awareness as the sense of vibration, often resulting in immediate decisions and reactions. To more robustly understand this sensory modality, and the centrality of its aggregate nature, we propose that our vibratory perceptual system should be addressed as the *Pacini system*.

Vibratory sensations, registered by the Pacini system, are integrated with other sensory modalities via multisensory integration. For example, our sense of subsonic vibration and our sense of sound are interlinked. Firstly, the stimuli of these two systems overlap, as both are activated by the subset of 20–300 Hz waves. Moreover, the sensory processing of these two systems may be more structurally and functionally interlinked than has previously been thought. For example, one particular structure of the midbrain, the inferior colliculus, is known to relay the distribution of afferent auditory signals to the auditory cortex during auditory processing (Aker, 2023). Recent studies have demonstrated that the inferior colliculus also integrates auditory signals with other sensory signals, including subsonic and low-frequency vibratory signals (Zia, 2024; Aker, 2023). When this multisensory integration happens, the inferior colliculus attenuates the strength of its auditory outputs, which leads to the amplification of vibratory signals. This results in dampened auditory perception on the one hand, and amplified vibratory perception on the other. This finding indicates that (a) sonic and subsonic sensory processing — via the auditory and Pacini systems respectively — are neurologically interlinked by inferior colliculus processing; and (b) this interlinkage has effects on conscious perceptual and sensory experience. In other words, the conscious sensory experience of subsonic vibration and of sound depend on one another. Future studies, for example on musical experience — particularly with subsonic and/or low-frequency tones, such as music with heavy bass — should

therefore include investigations of a broader suite of sensory modalities, including subsonic vibration.

2.2. Evolutionary perspectives on the Pacini system

The Pacini system sends its afferent signals to the brain through ‘fast fibres’ — the highest quality nerve fibres of the entire sensory system (Hunt, 1974). These fibres are preferentially used only by those sensory systems that have evolutionarily provided the most important and time-sensitive information — information that is often crucial to survival. The fact that the Pacini system uses these fast fibres suggests that evolutionary pressures led the body to prioritize the Pacini system as being among the most important of the peripheral senses. However, as the Pacini system has hardly evolved by predicting the importance of experiencing music with heavy bass, we may ask: why is the perception of low-frequency bass and subsonic vibrations such a high priority sensation?

Answering this question has led to the development of a working hypothesis presented here for the first time: *the Pacini system may have evolved to specialize in perceiving low-frequency sounds and subsonic vibrations that emerge from approaching threats, such as large animals, earthquakes, and volcanic eruptions. By registering these vibrations, the Pacini system alerts an organism to impending danger. It thus functions as a warning system crucial to survival.*

The scientific support of this hypothesis is already substantial, though future work is needed to help bolster this hypothesis (Kaplan, 2007; Hayakawa and Yamauchi, 2024). Firstly, the Pacini system is evolutionarily old. It is not only present in humans, but also in non-human animals including all mammals, birds, snakes, and insects, which have Pacini or Pacini-like mechanoreceptors (Dominy, 2009; Bouley *et al.*, 2007). Snakes, for example, lack inner ears and thus rely heavily on information registered by their Pacini-like systems in order to orient and respond to impending threats (Hayakawa and Yamauchi, 2024; Amassian, 1952).

Furthermore, functional brain imaging studies of Pacini system activation demonstrate an inherent link between Pacini system activation and subsequent affective and behavioural responses (Frakowiak *et al.*, 1997). These studies show that the afferent signals from the Pacini system are relayed in a structure called the ventral posterolateral nucleus of the thalamus (VPL), which receives both vibratory and pain sensory input (Kendroud *et al.*, 2022). The signals are then

distributed to the parietal lobe of the brain, which performs signal processing of somatosensory information, including location, strength, and type of input. However, the signals from the Pacini system are also sent to the limbic system (Frakowiak *et al.*, 1997; Verrillo, 2014), where affective responses and emotions like anxiety, terror, fear, and depression are processed (Pandya *et al.*, 2012). The Pacini system's processing in the limbic system thus closely links vibration to conscious affective experience. In other words, due to the Pacini system's limbic system processing, vibratory stimuli are inherently 'loaded' with affective information, which impels an organism to act immediately based on the sensation. Conscious experience of vibration thus draws on integrated information from both the parietal lobe (involved in somatosensory processing) and the limbic system (involved in emotion processing) in order to quickly engage relevant perceptions, affective responses, decisions, and actions — which all help an organism quickly and appropriately respond to, and therefore survive, impending threats.

Taken together, current evidence from neurophysiological and evolutionary studies therefore suggests that (1) the Pacini system is the highly specialized subsonic and low-frequency 'microphone' of our body (Bolanowski and Zwislocki, 1984; Nielsen *et al.*, under submission); (2) Pacini system activation modulates brain function and is interlinked with other sensory modalities (e.g. auditory processing); (3) the Pacini system and Pacini-like mechanoreceptors are evolutionarily ancient, conserved across species, and may function as a perceptual system that is capable of warning organisms about impending danger (Dominy, 2009; Hayakawa and Yamauchi, 2024); and (4) the Pacini system, via its limbic system processing, inherently links vibrations with affective experience, emotion processing, subsequent associated behaviour, and conscious experience (Frakowiak *et al.*, 1997).

2.3. Music perception and the Pacini system

To understand the role of the Pacini system in music perception, we now turn to a discussion of bass — which are low-frequency vibrations with frequencies around 20 Hz to 250 Hz. Given that low bass vibrations exist in most musical expression and that 'good' bass vibrations are perceived by many people as a very pleasant experience, we may ask: how can the Pacini system contribute to a pleasant bass experience if it likely evolved to warn against impending danger and

potentially elicit an emotion-laden, fight or flight reaction? Indeed it is this question that spurred author Nielsen's interest in vibration, music, and conscious experience, as exemplified in the vignette below:

When I was 15 years old my grandmother took me on a trip to London. We visited Westminster Abbey and my grandmother managed to sneak us into a service with the congregation. The event turned out to be very long and my Granny soon became impatient and was sitting restlessly on the church bench. I, on the other hand, was calm and alert, and very interested in the music that was being played. The congregation was performing the psalms in three voices. Then, the organ played an intermezzo. At some point the organist stopped playing with his hands entirely, such that at the end he played a scale solely on the pedals. With his feet he moved down, down, down the scale until he played the very last note, which was the deepest 'C' (probably 32 Hz) — the biggest pipe in the organ, played solo. Not a sound was heard in the air. Yet the furniture was vibrating heavily. I enjoyed this effect, but Granny had an acute panic attack. She grabbed her big hat, her bag, and me, and fled out of the cathedral with fear in her eyes.

What was it that led to such a different conscious and affective experience of the bass and subsonic vibrations for me and for my Granny?

While the effects of aging on the auditory system have been well-documented (Zheng *et al.*, 2024) and likely played a role in producing different auditory experiences during the service for young Nielsen and his Granny, the effects of aging on the Pacini system — which is what would have been activated in both during the final deep, vibratory, subsonic 'C' note — are not demonstrated (García-Piqueras *et al.*, 2019). So while age may have played a role in their differing auditory experiences, based upon current neurophysiological evidence we posit that understanding their differing reactions may also lie within the activity of the Pacini system — and specifically how it intersects with the *limbic system* and the *autonomic nervous system*. This is because Pacini system activation is processed in the limbic system, and bodily reactions to vibratory stimuli are executed through the autonomic nervous system.

2.4. The limbic system

The structures of the limbic system (e.g. the amygdala and hippocampus) are located deep in both hemispheres of the brain (Figure 1), and allow emotions and memories to influence autonomic, endocrine, and behavioural responses. Limbic system functions include processing of sensory input to produce emotional reactions like fear,

aggression, and pleasure, which in turn lead to behaviours like fighting, fleeing, or mating. Memories of past experiences are integrated into the current sensory input to more effectively engage — based on context and prior experience — the behaviours most appropriate or necessary for survival. The limbic system outputs through the hypothalamus to the autonomic nervous system, facilitating bodily reactions to the perceived situation and surroundings as well as conscious emotional experiences.

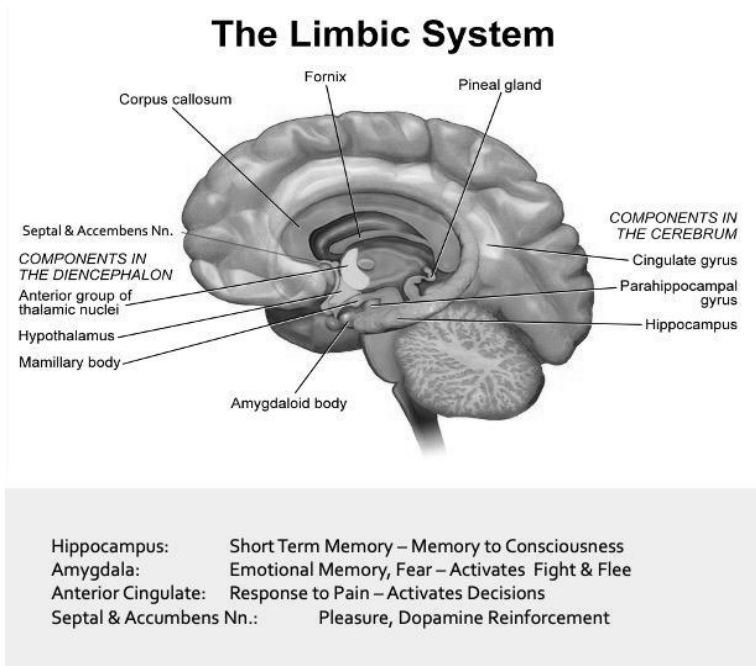


Figure 1. The limbic system. Courtesy of Blausen.com staff (2014) Medical gallery of Blausen Medical 2014, *WikiJournal of Medicine*, **1** (2). doi: [10.15347/wjm/2014.010](https://doi.org/10.15347/wjm/2014.010).

2.5. The autonomic nervous system: sympathetic and parasympathetic branches

The autonomic nervous system (ANS) is characterized by the ‘automatic’ control of body functions essential to survival, e.g. heartbeat, breathing, blood flow distribution, and various reflexes like pupil dilation and swallowing. ‘Automatic’ means that ANS activity is not necessarily dependent on conscious activity. For example, the ANS is

active during sleep and even in states of unconsciousness. However, the ANS is not solely ‘automatic’ but is closely connected to both the limbic system and the neocortex, which are heavily involved with emotion processing and other conscious processes. In other words, the ANS is widely influenced — but importantly, not mandatorily controlled — by ‘higher-order’ pathways and structures, which are linked to conscious experience, processing, and control. An example of this close and complex connection between the ANS and conscious experience is during music reminiscing, when just thinking or speaking about a beautiful moment in a piece of music may cause ‘goosebumps’ — which are caused by ANS activation (Reynolds, 2020). Conscious experience thus modulates (and is also modulated by) the ANS, and can alter ANS activity and its associated behavioural and emotional responses.

The ANS consists of two separate systems with ever alternating functions: the sympathetic system and the parasympathetic system. The seemingly ‘easy’ split between the sympathetic and parasympathetic systems that follows is an oversimplification, but it is nevertheless useful to illustrate the relationship between the limbic system, ANS activity, Pacini system activation, and HALF-MIS outcomes.

Activation of the *sympathetic system* causes the release of excitatory neurotransmitters, e.g. norepinephrine, and executes through its efferent fibres the increase of heart rate, blood pressure, respiratory rate, sweating, release of (stress) hormones, and distribution of blood to the muscles (Coon, 2025). During sympathetic activation, senses are heightened and muscles are ready for speed and power. Pupils dilate. Perfusion of blood is shifted from the gut to the muscles. Mood is alert and aggressive. This state of the brain, body, and conscious experience, driven by norepinephrine release, is a prerequisite for the ‘fight or flight’ response, which we will call, for the purposes of this article, the ‘norepinephrine-state’. This sympathetic state is resource intensive and costly to maintain, so the body regularly transitions to another state to force a downregulation of norepinephrine.

Downregulation of the sympathetic state is achieved through the opposing *parasympathetic system*. Activation of the parasympathetic system causes the release of inhibitory neurotransmitters, e.g. GABA, in the brain (Chen and Sharma, 2025). When the GABA neurotransmitter takes over, the effects on the body are a decrease in blood pressure, pulse, respiration, and sweating, which allows for the brain to rebuild its resources. Perfusion of blood is shifted from muscles to gut and reproductive organs, preparing the body for the ‘rest and

digest' state, or, as we will call it for the purposes of this article, the 'GABA-state'. Mood is calm and reflective, and instead of fighting or fleeing, a person will engage in restful, social, creative, and/or spiritual activities like music and singing (Cournoyer Lemaire and Perreault, 2024). As will become important later, the vagus nerves contain many parasympathetic fibres – therefore stimulation of the vagus nerves will result in an increase of GABA in the brain and body, often resulting in an activation of this GABA-state.

Again, these characterizations of the ANS's sympathetic and parasympathetic systems, and the norepinephrine-state and GABA-state, are simplifications of what are in reality much more complex processes. We nevertheless sketch their differences in these simplified ways because they illustrate key 'state' differences of brain, body, and experience. These 'state' differences, which differentially enable and constrain various capacities of perception, emotion, cognition, and action (Luecke 2022), matter in our present discussion of Pacini system activation, HALF-MIS, and their relations to music, consciousness, and health — and as we will see, may be at the core of answering the question of why young Nielsen and his Granny had such different responses to the deep 'C' note in Westminster Abbey.

The state that the body and brain are in shapes subsequent information processing, responses to stimuli, and emotional experience (*ibid.*). For example, the brain processes stimuli differently when in the norepinephrine-state vs. the GABA-state. If a person suddenly encounters a snake in the wild — i.e. an angry cobra — their sympathetic system will be activated immediately, flooding their brain with norepinephrine, which may induce an intense sense of fear. The person will likely run away with a hammering heart. On the other hand, if that person is in a zoo, and encounters the same snake species in a terrarium and experiences it from behind the safety of glass, their brain will likely stay in a GABA-state, and the person will be able to relax and enjoy the snake's beauty. Furthermore, recent studies have shown that mechanoreceptor activity, in particular, influences the state of the brain by entraining subsequent neural activity, neurotransmitter release, information processing, and health-related behaviours (Wang and Hamill, 2021; Luecke, 2022; Liu *et al.*, 2025).

Given these details about limbic- and ANS-regulated 'state' difference of body and mind, as well as the role of mechanoreceptors in entraining these states, we therefore hypothesize that *when a person is in a norepinephrine-state, activation of the Pacini system by vibrations will produce a conscious affective experience of danger and*

fear, and potentially a fight or flight reaction. But when the person is instead in a GABA-state, activation of the Pacini system by vibrations will instead produce a pleasant bass experience, accompanied by feelings of peace and beauty.

These details may help explain the differing reactions between young Nielsen and his Granny when exposed to the same subsonic ‘C’ note from the great organ of Westminster Abbey: Nielsen, who was calm and alert (i.e. likely in a GABA-state), enjoyed experiencing the vibratory sensations emanating from the deep ‘C’. But his Granny, who was already impatient and restless (i.e. likely in a norepinephrine-state), fled the scene with fear in her eyes as soon as the deep ‘C’ vibrations started.

If this hypothesis is corroborated, HALF-MIS — which intentionally stimulates the Pacini system via subsonic and low-frequency vibrations — will only work if a person is already in a GABA-state. Otherwise, if the person were in a norepinephrine-state, they might experience the HALF-MIS vibrations as uncomfortable, distressing, and indicative of danger.

2.6. Pain, the vagus nerve, and the Pacini system

There is a structural overlap between the Pacini system and the pain processing system. As described above, the afferent signals from the Pacini system are relayed in the VPL and then projected to several structures in the limbic system and in the brainstem (Figure 2). In the pain pathway (the C-fibre system), all signals pass through this exact same nucleus, the VPL, on their way to the limbic system, where emotional experiences, conscious experiences of pain, and pain-related reactions are elicited (Frakowiak *et al.*, 1997; Kendroud *et al.*, 2022; Yang and Chang, 2019). Furthermore, the projections of the pain processing structures to the limbic system are almost congruent to the structures involved in the processing of vibratory signals of the Pacini system. Importantly, these same structures are also implicated in the development of depression and anxiety symptoms (Sigurdardóttir *et al.*, 2019; Pandya *et al.*, 2012).

The Pathways of Pain & the Pacini System

The Parietal Cortex, S1 & S2
 Anterior Cingulate Gyrus
 VPL of Thalamus
 Septal & Accumbens Nn.
 Amygdala
 The Brain Stem
 Medulla Spinalis
 Dorsal Column Fibers
 Anterior Column Fibers
 From the Pacini System,
 Somato-Sensory Afferents
 From Pain system, C-fibers

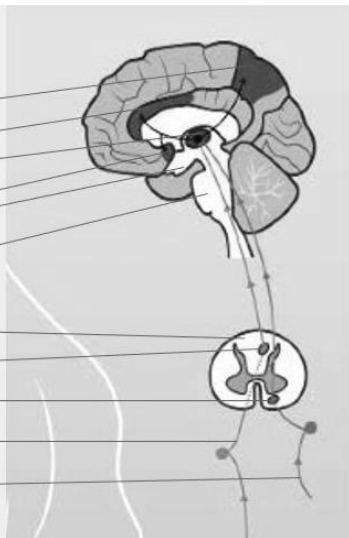


Figure 2. Pathways of the pain and Pacini system. Courtesy of the HALF-MIS research group.

The Pacini system is also structurally and functionally linked to vagus nerve activity. Mammals, including humans, have two vagus nerves — one on the left side of the body, and one on the right. The vagus nerves are called ‘mixed nerves’ because they contain both motor and sensory nerve fibres as well as autonomic, parasympathetic fibres (i.e. to the swallowing reflexes). And as was discussed above, vagus nerve stimulation often leads to an increase in the release of GABA. *Vagus* in Latin means ‘the widely wandering’ and indeed the vagus nerves connect the brainstem to many different functions and structures throughout the body, including the upper abdominal inner organs (Schuerman *et al.*, 2021; Amassian, 1952). Importantly, the vagus nerves are the most important pathway for sensory output from the upper internal organs — including from the fast fibres of the abdominal Pacini system (Figure 3). In fact, the afferents from the upper abdominal Pacini system have a pathway through both of the vagus nerves, which inherently links abdominal Pacini system activity with vagus nerve activity.

The Vagus Nerve Pathway

- Prefrontal Cortex
- Anterior Cingulate Gyrus
- VPM of Thalamus
- Septal & Accumbens Nn.
- Amygdala
- N. Tractus Solitarius
- Vagus Nerve
- The Pacini System, Abdominal

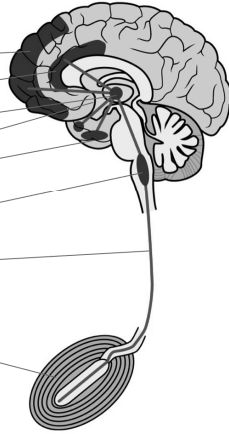


Figure 3. Signals elicited by the stimulation of the upper abdominal Pacini system and of the free nerve endings of the vagus nerves are collected in the NTS, relayed in the VPM, and then distributed to various structures of the limbic system and to the prefrontal cortex. Courtesy of the HALF-MIS research group.

These details provide the neuroscientific foundation for the potential mechanisms of action of sonic and subsonic health interventions and treatment modalities, particularly those that target pain, depression, and anxiety (Cournoyer Lemaire and Perreault, 2024). In developing the HALF-MIS treatment, we have therefore incorporated research on various interconnected neurological pathways (e.g. the limbic system, ANS, vagus nerve, and pain processing) — and the health issues that are associated with their mis- or dysregulation — along with research on the Pacini system and its abilities to register subsonic and low-frequency vibrations in a way that may alter subsequent neuronal processing and conscious experience. In order to be effective, HALF-MIS thus first stimulates a patient to enter the GABA-state by playing calming music, and only then stimulates the Pacini system with subsonic and low-frequency vibrations.

3. High Amplitude Low Frequency Music Impulse Stimulation (HALF-MIS)

3.1. Sonic components of HALF-MIS

HALF-MIS incorporates specifically designed, composed, and produced music that delivers an harmonic sonic experience in addition to powerful subsonic and low-frequency bass stimulation. The development of the sonic components of HALF-MIS builds upon the above-mentioned research on the differences between the norepinephrine-state and the GABA-state, and the role of conscious and emotional experience in the processing of subsequent stimuli, including vibratory stimuli via the Pacini system.

The development of the audible musical compositions used in HALF-MIS was driven by author Nielsen's own music performance experience as well as by feedback from patients who were testing the device in its early stages of development. Through trial and error, we found that the duration of a HALF-MIS treatment session must last around 30 minutes to get the sufficient 'dose' of subsonic and low-frequency bass. This length of time calls for 'symphonic' thinking for the sonic components of the treatment, requiring musical and emotional progressions in the compositions to keep the patient engaged and listening.

The purpose of the audible music is to calm the physical, mental, and emotional state of a patient and tune them towards the GABA-state — in other words, an experiential state of complete relaxation with maintained alertness. The compositions must therefore follow musical progressions that induce calm and avoid stressful elements. For example, we incorporate harmonies that are experienced by patients as beautiful rather than as discordant; progressions described as meaningful rather than dissonant; flowing dynamics with no sudden bursts of sound; tempo that is moderate to slow (40–80 BPM); and no melody lines, which at times have annoyed patients, who listen to the pieces repetitively and sometimes get tired of melodic repetitions. In summary, our pilot trials using HALF-MIS with patients in clinical settings have shown that the music compositions must be simple but never boring, calming but never sleep inducing. This is achieved by adding a rhythmic concept with a sequential arrangement of percussion: each instrument follows the beat but plays different tact counts: 3/4, 4/4, 5/4, 7/4. In this way, no event is ever repeated and the

details and variations will trigger curiosity and keep the listener calm but alert.

Elements of reminiscence and nature immersion are integrated into each musical composition. Glimpses of birdsong and gentle sea waves can be heard. For example, the birdsong is a sequential composition with samples of birds from Danish woods. The waves are recorded from Danish beaches. Patient feedback tells us that they look forward to the beautiful moment when they first hear the birds in the composition, and that the rhythmic wave sounds bring them away from feelings of stress.⁴

These types of compositions have enabled patients to become calm and relaxed while still sustaining their capacity to listen attentively, leading to conscious experiences of heightened calm and focus, with a narrowed awareness — allowing for musical absorption and even mind-wandering (Høffding, Nielsen and Laeng, 2024). We hypothesize that this altered state of consciousness, induced by the music, contributes to the balancing of neurotransmitter releases, paving the way for the GABA-state that facilitates a calming rather than stressful response to the subsequent subsonic and low-frequency vibratory stimulation.

3.2. Subsonic components of HALF-MIS

As mentioned above, corpuscles of the Pacini system are densely expressed not just in the skin, joints, and ligaments, but also in the inner organs of the abdominal cavity (Yang *et al.*, 2025). The function of the latter has not been well researched. Nevertheless, we took advantage of the high concentration of Pacini corpuscles in the abdomen and built a custom-made subsonic abdominal transducer into the HALF-MIS system. This transducer is placed on the stomach of the patient and allows for subsonic vibrations to be played with full power, without creating any audible noise in the room. Simultaneously, HALF-MIS sonically stimulates the ears by playing the original music compositions through high quality headphones. Please see Figure 4 for a diagram of the complete HALF-MIS set-up.

⁴ For excerpts of the musical component of HALF-MIS, please follow this link: <https://www.dropbox.com/scl/fo/m9cjbliq5r3ngb4tuc3cw/AAIC4vM2SzIZVBFjuGEq5VU?rlkey=5e3zw8vwi3xuzu81u3qp82rtm&st=m3hpfmqj&dl=0>



Based upon these clinical observations, we therefore propose that *the Pacini system is highly astute and has a very fine-grained acuity. These results suggest that subsonic frequencies, perceived by the Pacini system, may also be vital to the conscious experience of music, despite the fact that they are auditorily imperceptible.*

We now present three case studies, as well as several clinical trials that emerged from their insights, that showcase the initial results of

the HALF-MIS treatment. HALF-MIS has been investigated for observational purposes in patients with a variety of physical and mental health conditions. Setting up clinical trials with HALF-MIS as the treatment has been challenging as the treatment cannot yet be blinded or placebo controlled; thus a cross-over design is not feasible. Nevertheless, several randomized controlled trials (RCTs) have been conducted, as presented below.

4.1. Case study 1: long COVID-19

A 32-year-old previously healthy woman contracted COVID-19, which progressed to acute respiratory distress syndrome. She required admission to intensive care, where her condition gradually improved. However, as her acute illness resolved, she developed persistent long COVID-19 symptoms including chest pain, headaches, complete loss of smell and taste, severe fatigue, and cognitive dysfunction including memory and concentration deficits. These impairments left her unable to care for her two young children or manage her home, and she had no prospect of returning to work. Her symptoms persisted for more than three months without improvement.

She was enrolled in a series of experimental HALF-MIS sessions, each lasting 24 minutes and delivered at least three times per week. After only three HALF-MIS treatments, her pain was significantly reduced. After the fifth treatment, her senses of smell and taste began to return, much to the surprise of the clinicians. After one month of treatment, her fatigue and cognitive impairments had improved to the point where she could gradually resume her daily responsibilities at home and work. Within three months of treatment, she was back to full-time employment and discontinued the treatment. Later, following a flu-like viral infection, she experienced a relapse of symptoms. Once again, her symptoms responded quickly to a brief course of HALF-MIS treatment.

Because HALF-MIS appeared effective in alleviating multiple of the patient's long COVID-19 symptoms — not just her pain — a pilot RCT was conducted to investigate the effects of HALF-MIS on long COVID-19 symptoms including chest pain, headache, loss of smell and taste, fatigue, and cognitive deficits in the form of impaired memory, concentration, and exhaustion (Nielsen *et al.*, under submission). Patients were enrolled in this study if they experienced over three months of long COVID-19 symptoms with no effect from any other treatment modality. Forty-four patients were recruited from

Danish long COVID-19 clinics using a ‘Stepped Wedge’ method where the patients act as their own controls. The 44 patients were randomized into four groups. All groups received 24 HALF-MIS treatments across the span of one month. The first group was treated the first month, the second group the second month, and so on. All groups were interviewed with a comprehensive questionnaire to monitor the development of both physical and mental long COVID-19 symptoms. The interviews were carried out at the time of inclusion in the study, as well as each subsequent month, until all groups had finished their treatments plus a follow-up.

The effect of HALF-MIS proved to be highly significant in alleviating many long COVID-19 symptoms, including pain and loss of taste and smell. Most important for the patients was the increase in the overall measure of their functional level and ability to work. The findings of this study, currently under submission, demonstrate with high statistical significance that HALF-MIS may be the first evidence-based treatment that shows measurable effects in treating multiple symptoms of long COVID-19.

4.2. Case study 2: spinal cord injury and neurogenic pain

A 51-year-old man sustained a high cervical spinal cord injury following a bicycle accident. He presented with complete quadriplegia and sensory loss in the limbs, while cranial functions — including breathing, speech, and swallowing — remained intact. Within a few months, he developed severe neurogenic pain, describing his paralysed body as burning ‘like fire’. Despite treatment with 30 different medications targeting both central and peripheral mechanisms, his pain was unrelenting and intractable. He was unable to sleep, eat, or rest, and spent his days and nights in agony.

Given his critical state, the clinical team initiated experimental HALF-MIS treatment. Sessions were delivered four times a week. After one month of treatment, his pain was sufficiently reduced to allow tapering of his medications to one third of the previous load. He could then finally participate in rehabilitation, including learning to operate a mobility device with his chin. After three months, he was discharged to a nursing home.

A personalized HALF-MIS system was later installed at his residence, allowing him to use headphones and a subsonic transducer placed on his abdomen, with support from caregivers. He still continues nightly sessions — three consecutive 24-minute treatments —

which provide lasting relief and allow for restorative sleep. With improved quality of life, he has been able to acquire an apartment by the seaside, where he regularly drives his mobility device, accompanied by his caregivers. The patient remains committed to the original music track and refuses any alterations, underscoring his view that the composition is not entertainment but an essential therapeutic tool. A follow-up RCT was initiated to further investigate HALF-MIS treatment on musculoskeletal pain (Eshuis *et al.*, 2021), which was unfortunately terminated due to the COVID-19 pandemic.

Furthermore, his caregivers noted a striking and unexpected effect of the treatment on his muscle spasticity. Thirty seconds into the treatment, when the recorded sound of songbirds plays, the patient's contracted arms and hands begin to relax, even before the subsonic stimulation has commenced. This timing suggests an anticipatory response, mediated by the music itself, highlighting the combined importance of both the auditory and vibrational components in the treatment's efficacy.

4.3. Case study 3: stroke, pain, and depression

A 74-year-old woman suffered a right thalamic hemorrhagic stroke, resulting in severe left-sided spastic hemiplegia and central post-stroke pain. She described the pain as constant, burning, and unbearable, resistant to both standard analgesics and specialized neurogenic pain medications. The intensity of her symptoms left her sleepless and profoundly distressed.

A regimen of HALF-MIS, three times weekly, was launched. Before she began her treatment, she also displayed features of clinical depression, including sadness, anxiety, and psychomotor slowing. Because of this, her general practitioner also initiated antidepressant medication the day before her first HALF-MIS session.

After only three HALF-MIS sessions, her pain improved significantly. Unexpectedly, her depressive symptoms also resolved rapidly — too quickly to be attributed to the antidepressant medication, which typically requires several weeks to take effect. Encouraged, the patient requested an increased 'dose' of HALF-MIS, leading to an experiment with two consecutive HALF-MIS sessions. This approach was able to control her pain for up to 48 hours.

Furthermore, the patient's paralysed arm and hand exhibited spastic flexor contraction, but following two consecutive HALF-MIS sessions, her limb was fully relaxed and amenable to therapeutic

intervention. However, this effect was temporary, lasting only a few hours. Further research through RCTs is required to explore the potential of HALF-MIS in treating muscle spasticity.

In response to this patient's unanticipated antidepressant effect of HALF-MIS, a pilot RCT was conducted in collaboration with the Center of Psychiatry, University Hospital of Copenhagen, to investigate the effect of HALF-MIS on depression symptoms (Sigurdardóttir *et al.*, 2019). Patients were recruited from the department intake. Patients with moderate to severe depression in need for admission to hospital were included and randomized into two groups. The first group was treated conventionally with selective serotonin reuptake inhibitor (SSRI) medication. The second group likewise, but with an add-on of eight treatments of HALF-MIS, two per week. Both groups were scored with a state-of-the-art depression scale (Hamilton 17 & 6) before treatment, at discharge, and at a later follow-up. The effect of HALF-MIS was highly significant with a reduction of depressive symptoms about four times greater than in the conventional SSRI group. A few of the patients even considered themselves to be cured after the HALF-MIS treatment, and stopped their SSRI medication entirely. The findings of this study indicate a highly statistically significant therapeutic efficacy of HALF-MIS as an adjunctive treatment for depression (*ibid.*).

Each of these case studies, as well as the RCTs that emerged from them, demonstrate the potential efficacy of HALF-MIS as a treatment for a wide variety of health conditions, including post-stroke muscle spasticity, neurogenic pain from spinal cord injury, depression, and multiple long COVID-19 symptoms. While the exact mechanisms of action are as of yet unknown and require further research to determine, we now turn to discuss them.

5. Potential Mechanisms of Action

HALF-MIS is a new non-pharmaceutical, non-invasive, non-electric, and non-radiative treatment modality that leverages sonic and subsonic frequencies to seemingly relieve patients from a variety of symptoms and conditions that affect health and well-being. Furthermore, patient feedback suggests that undergoing HALF-MIS may be experienced as pleasant, relaxing, and a beautiful musical experience.

It is not yet clear whether it is the sonic musical components, the subsonic vibrations activating the Pacini system and thereby the vagus nerves, the altered attention and awareness from being in a new,

somewhat unusual, and experimental treatment situation, or the reported ‘pleasantness’ of the treatment that works. It is likely a combination of all of these factors. In the section that follows, we carefully work through the available evidence to begin to make sense of the potential mechanisms of action of this treatment.

Firstly, HALF-MIS stimulation may be considered to be a new type of vagus nerve stimulation. Recall that the afferents from the upper abdominal Pacini system — which are purposefully activated during HALF-MIS treatment — have a pathway through both vagus nerves. Abdominal Pacini system stimulation thus stimulates both vagus nerves. For decades, electric vagus nerve stimulation, or VNS, has been an evidence-based treatment for severe cases of epilepsy, chronic pain, chronic depression and anxiety, and chronic inflammatory diseases (Johnson and Wilson, 2018; Ben-Menachem *et al.*, 2015; Chen and Liu, 2025). The brain cortical representation of VNS is well described (Figure 3) with a relay in the medulla oblongata (NTS), the VPM nucleus of the thalamus, and projections to the limbic system and the prefrontal cortex, which are implicated in depressive symptoms (Pandya *et al.*, 2012). This localization may explain VNS’s ability to treat depression symptoms like slowing of psychomotor functions and lack of initiative, ideas, working memory, and self-esteem (Johnson and Wilson, 2018). Importantly, the neurochemical effects of VNS revolve around balancing the release of GABA, norepinephrine, and other neurotransmitters, with the release of GABA often being upregulated (Ruffoli *et al.*, 2011).

However, traditional VNS treatment is extremely unpleasant. The most efficient VNS systems necessitate the implantation of a pacemaker-like device in the chest wall, which is an invasive procedure. Furthermore, the electrical stimulation of traditional VNS has numerous side effects involving painful efferent effects from the vagus nerve, including loss of voice, bowel issues, lung trouble, and even heart arrhythmia. Newer VNS devices have therefore been designed to instead stimulate a small sensory branch of the vagus nerve in the outer ear. These, however, are less efficient in providing symptom relief (Schuerman *et al.*, 2021). Importantly, all existing VNS devices stimulate only one of two vagus nerves.

On the other hand, HALF-MIS treatment bilaterally stimulates *both* vagus nerves, which maximizes action potentials in the vagus nerve pathways and likely leads to intensified VNS health outcomes like reductions in pain, depression, and anxiety. Furthermore, unlike traditional VNS, vagus nerve stimulation via HALF-MIS is non-

invasive, and has been observed to be exclusively afferent — in other words, there are no negative efferent side effects that have yet been reported.

Given the structural and functional overlaps between Pacini system activation, VNS treatment, and pain pathways discussed above, we hypothesize that *a treatment modality built to induce a maximal stimulation of the abdominal Pacini system may succeed in several aspects of neuromodulation that are as of yet unattainable via existing traditional VNS or pharmaceutical-based treatments for pain, depression, and other related health conditions.*

For example, in HALF-MIS, pain relief might be achieved by an overload of vibratory stimuli reaching the VPL via the abdominal Pacini system. This overload could inhibit painful stimuli from reaching the VPL via the C-fibre system (used in pain processing). In other words, by blocking the VPL relay pathway (which is used by both vibratory and pain sensory systems), vibratory processing may block pain processing by a mechanism similar to ‘gate control’ (Melzack, 1996). The result of this blocking would be pain relief, as was observed in all three case studies.

Similarly, an overload of vibratory stimuli reaching the limbic system via the Pacini system could block these structures, which are implicated in the development of depression and anxiety symptoms (Pandya *et al.*, 2012). Overloading the limbic system with vibratory processing could thereby alter emotion processing and conscious affective experiences, which may help explain the alleviation of depression symptoms that was observed in Case Study 3.

In attempting to understand the alleviative effect of HALF-MIS on long COVID-19 symptoms like loss of taste and smell, our preliminary explanation draws from our understanding of other chronic cognitive conditions that may be alleviated by HALF-MIS, including concussion, depression, anxiety, and fatigue. Currently accepted hypotheses assume that the chronic nature of many symptoms expressed in long COVID-19 are sustained for many years by an apparently irreversible central sensitization of pain perception and an imbalance of neurotransmitters, which locks pain processing in a ‘vicious circle’ (Goldenberg, 2025; Nielsen *et al.*, under submission). Most medical treatments for long COVID-19 trialled thus far have unfortunately not been able to break this chronic cycle. On the other hand, the preliminary evidence presented in the case studies and clinical trials above suggests that VNS, specifically in the form of HALF-MIS treatment, may be able to relieve this central sensitization.

We hypothesize that HALF-MIS does so by using sonic musical elements to enter a GABA-state, and then stimulating the abdominal Pacini system via subsonic and low-frequency vibrations to bilaterally activate the vagus nerves, thereby activating the parasympathetic system in a sustained way, restoring GABA balance, and reversing i.e. long COVID-19 symptoms. The results from the long COVID-19 RCT above support this hypothesis, and an fMRI investigation is in preparation to chart the full cortical representation of HALF-MIS treatment.

6. Concluding Thoughts

We have presented the initial findings of the HALF-MIS treatment — which purposefully activates the Pacini system to alleviate a broad variety of neurological and psychiatric symptoms. While a significant amount of future research — for example fMRI studies of the cortical representation of HALF-MIS treatment, and multicentre clinical trials on the effects of this treatment on various health conditions — is necessary to further detail the effects of HALF-MIS treatment, understand its mechanisms of action, and prove its efficacy, preliminary findings about the use of this treatment modality are already well supported by evidence from a variety of scientific disciplines, on experience from the fine arts, and from ongoing clinical trials. As such, HALF-MIS provides several promising avenues for further research in the role of music experience (both sonic and subsonic) in mental and physical health.

We have identified support for our hypotheses of the potential mechanisms of action wherever possible by drawing on the existing literature on the Pacini system and its relationships to music perception, the limbic system, the autonomic nervous system, pain processing, emotion processing, and vagus nerve stimulation. We present this ongoing work at an early stage of clinical and scientific development due to its potential to influence a wide variety of existing and future treatments, as well as to initiate further research and clinical studies, which are needed to corroborate these hypotheses and more concretely characterize the relevant mechanisms of action, both neurophysiological and experiential. As such, HALF-MIS presents itself as not only a promising new treatment for a number of health conditions that may be intractable to more traditional treatments, but also as a tool for further research across neurophysiological, music, and consciousness studies, particularly as they relate to health and well-being.

HALF-MIS modulates conscious experience, utilizing both sonic and subsonic stimulation to change the neurophysiological, bodily, and experiential state of patients. At the same time, HALF-MIS is also modulated *by* conscious experience. In Case Study 2, for example, the patient experiences relief from his muscle spasticity symptoms (which is thought to be an effect of subsonic stimulation) during the initial musical component, *before* the subsonic treatment even starts. This effect is unexpected and warrants further attention, particularly as it relates to debates about ‘top-down’ versus ‘bottom-up’ processing in consciousness studies (Høffding and Satne, 2021; Finke and Solli, 2025), and whether this distinction is even useful or warranted. In any case, this observation likely showcases the importance and influence of the patient’s expectations on his experience with and response to HALF-MIS treatment. For this patient, it is not necessarily (or not necessarily only) Pacini system activation and VNS that trigger his relief, but rather his conscious experience of the treatment’s musical elements and his expectation of the impending soundscape that trigger relief from his symptoms. Conditioning by repetition over time may have caused the familiar sonic elements to trigger the subsonic effect ‘early’. However, other explanations may be possible, so we encourage scholars to take up this finding.

Given the potential evolutionary function of the Pacini system as a sensory modality capable of detecting vibrations inherent to impending danger, we have explored how one’s bodily and experiential state (e.g. norepinephrine-state vs. GABA-state) may influence the subsequent perception of, and reaction to, subsonic and low-frequency vibrations. This discussion highlights that the outcome of HALF-MIS is modulated by context, producing differing experiences and reactions depending on how and when the vibratory stimulus is received (Luecke, 2022). It also troubles the distinction between ‘automatic’ and ‘conscious’ in that ANS activity and conscious experience are intimately interlinked and dynamically interact. HALF-MIS and Pacini system activation show that music perception is an example of this ongoing, dynamic process, which warrants further scholarly attention. Furthermore, the findings about patients’ fine-grained acuity in perceiving slight fluctuations in subsonic and low-frequency bass stimulation, and how these affect their emotional state and overall treatment experience, suggest that subsonic vibrations, registered by the Pacini system, may also be vital to the conscious experience of music, health, and well-being, despite the fact that they are auditorily imperceptible.

In sum, HALF-MIS highlights the importance of subsonic and low-frequency vibrations — which are often overlooked — in conscious experience, music perception, and health. The case studies and clinical trials indicate preliminary evidence for the efficacy of incorporating subsonic and low-frequency vibrations and purposeful Pacini system activation into music-based treatments that aim to enhance a variety of physical and mental health outcomes.

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