The Effects of Spatial Sound on Human Wellbeing

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Version Published
26 July 2021

SUMMARY
The emerging research into spatial sound as a medium, in conjunction with recent technical developments in spatial sound processing and acoustic holography, provides a new field of study that may further the understanding of the principles of sound wave propagation and how to make use of its potential effects on human wellbeing. Prior studies conducted during recent years show that spatial coherence of sound waves may have a distinct effect on harnessing energy in natural systems, such as improved homeostasis in the human body. Spatial coherence of sound is understood as the alignment of sound waves in specific symmetrical patterns and the amplification of associated harmonic spectra as a result, which coincides with an observed improvement of the physiological and psychological state of subjects exposed to the sound waves. We consider these aspects to be intertwined as part of a unified non-discrete system, meaning the connectome of various natural systems bound by the fundamental principle of syntropy (negentropy). This notion informs and gives rise to the hypothesis that spatial projection of sound may provide a means for Acoustic Effector Stimulation (AES) to help restore, maintain and optimize balance in cell organisms, implying potential applications for treatment and prevention of pathological conditions associated with disease and trauma.

BACKGROUND

In support of the hypothesis, we propose a discussion of relevant findings in the fields of acoustics, archaeoacoustics, physics, neurophysiology, embryology, biology and genetics, inconjunction with clinical observations in sound and music therapy.

A recent study tested the hypothesis and measured behavioural change, brain wave activity, heart rate and blood pressure levels of 50 subjects in response to continuous sound stimuli in an interval of an octave (272.2Hz : 544.4Hz) projected as a virtual sound source having a geometrical shape, also referred to as Geometrical Sound (GS). Subjects were exposed to three GS conditions (Pyramid, Cube, Sphere) and control (stereo). Results on all measures showed GS had a direct effect on the propagation patterns of the sound waves, as well as influenced the topology, power amplitude and connectivity patterns of brain waves of subjects. Results show an increase in reported positive feelings and decrease in reported negative feelings in conjunction with reduced blood pressure and heart rate for all subjects inresponse to GS compared to control. The study effectively showed that spatial-geometrical modelling of sound affects the human physiology differently than using the same sound source in standard stereo positioning[1].

In the reference study, advanced spatial sound technology is used as a transmitter-enabler of the observed phenomena and as such, it provides a non-invasive method to establish equilibrium in physiology, i.e. homeostasis in the human body [2]. At present, prototype devices are being developed that integrate new methods in spatial sound processing and acoustic holography [3, 4] to enable accurate projection of virtual sound sources with a dimensional shape, size and density, using omnidirectional loudspeakers [5] and vibro-transducers. An example of such a device is the Sphere, a fully spherical construct for one person to sit within, providing an acoustic precision instrument for the projection of virtual sound sources with distinct spatial characteristics. The Sphere offers an environment for high-fidelity spatial projection of sound and integrates measuring human response to the sound stimuli at various levels – such as the brain wave activity and vital functions [6].

For a further explanation of the observed effects, we consider the hearing as a vibro-tactile sense that is at the foundation of the formative embryonic period of human life in the womb. Hearing develops significantly earlier than other senses such as sight, scent and taste. The auditory system of the fetus is already fully formed by the sixth month of pregnancy, whereas reception of sound vibrations by means of the entire body may already develop within the earliest stages after conception. The ears and hearing sense develop in what could be recognised as an internal relation to the formation of the vibratory pulsating organ of the fetus' own heart, with the apical end of the cochlea being more sensitive to low frequencies in the evolving fetus [7]. Through the liquid environment of the womb, the fetus can feel and hear vibrations of itself and its surrounding coming from the mother's body, e.g. the various sounds within her body and external sounds coming from the mother's environment. It is postulated that the fetus responds to sound and uses the energy it receives from sound waves to shape the development of the ears, nervous system and the brain [8], all evolving from the same ectoderm [7]. Sound, both as a vibratory and acoustic medium, performs as a communication module for the fetus. Newborn babies were found to cry in the melody of their mother's language just seconds after birth, suggesting tonation, rhythm and melody, all crucial aspects in characterizing different languages, to function as a means of primordial localisation and connection to the environment [9]. Furthermore, hearing is reported as one of the last senses to remain active before death [10]. Considering sound plays such a crucial partin our life from gestation to death, it may be a fair assumption that sound has an indispensable vital effect on the human body. Our physiological balance mechanism also resides in the inner ear regulated by the vestibular function, further suggesting homeostasis in various physiological systems of the human body may have a fundamental connection to the auditory faculty.

The notion that sound and its innate rhythms provide balance to our physical and emotional state is fundamental to every form of vibratory medicine, including music therapy, vibratory medicine or sound therapy. Such methods generally aim to (re-)balance the state of the body and the mind and its interdependent elements, potentially restoring or preventing disruption in physiological, mental and emotional processes. Accumulating scientific research in the fields of music therapy and sound therapy confirms the positive effect on brain waves and emotion regulation [11], secretion of hormones [12], pain relief mechanisms [13], improved mood and sense of wellbeing [14], improvement in brain impairment conditions such as a stroke [15], psychological conditions such as a bi-polar disorder [16], enhanced blood oxygenation [17] and more.

While the positive emotional effect of listening to music is intuitively familiar to almost anyone, the positive effect of sound as a medium may be more elusive to comprehend. In vibratory medicine it is common to relate to the entrainment of frequencies and rhythms as the driving mechanism to harness and regulate homeostasis. From

heartbeat and breathing to circadian rhythms and menstruation cycles, the human body generates and operates according to rhythms of various periodicities which govern biological, cellular and mechanical processes. It is assumed that sound, being inherently rhythmic by its frequency oscillation components, can affect other vibratory systems, i.e. oscillation cycles occurring in biological and natural systems, including the rhythms of the human body. The equilibrium state is observed to be positively affected or tune-able, i.e. the process referred to as entrainment.

We consider the entrainment of physiological systems to distinct sound frequencies as a form of harmonic resonance, where a response function is generated between two seemingly discrete systems, e.g. the human body and an (external) sound source. The effects of harmonic resonance have been widely demonstrated in physics [18] and have also been observed in human brain networks [19] and bilateral functioning of the heart and brain [20]. Harmonic resonance describes the phenomenon where wave oscillations are increasingly amplified at a closely matching frequency and its higher harmonics, which are integer multiples of the fundamental frequency. Harmonic resonance exhibits in standing waves that propagate geometrically in space, with a wavelength that is inversely proportional to the frequency. States of harmonic resonance may be expressed in frequency ratios and patternsof spatial distribution. The most prominent frequencies of the observed standing wave statescorrespond to the ratio of the lowest Pythagorean harmonic intervals 1:2 (octave), 2:3 (fifth) and 3:4 (fourth) and further permutations of these intervals [21]. While being deflected from stillness by the vibratory excitation, a system under influence of harmonic coherence demonstrates a restored state of equilibrium, associated with an increase in energy stored and decrease in energy dissipating from the system. As such, we observe *syntropy*, or negative entropy, brought about by harmonic resonance, a condition where organisation in the system is enhanced and energy is locally preserved and accumulates. We refer to syntropy as the tendency towards energy concentration, order, organisation and life, or inversely to entropy, as a result of retrocausality leading to persistent organisation [22].

Here it should be noted that since early development of civilization, humanity has deployed and created physical structures that harness harmonic resonance, possibly with the intentionto enhance physical, emotional and spiritual wellbeing. These structures are found across cultures around the world using stones and rocks with bell-like characteristics [23-28]. Such structures may have functioned as amplification devices for natural sound sources in the environment, such as the human voice or primitive instruments, and may have been used to harness geophysical properties for the benefit of acoustic resonance and its effects on the human body and mind. The positioning of individual elements of these structures, as well as the architectural and geographical relation between these structures were often found to follow various geometric designs and distinct mathematical ratios, such as the Fibonnaci series and other mathematical constants [29-30]. The geometric organisation of the environment using distinct shapes, measures and materials enhances harmonic resonance at distinct frequencies and/or frequency ranges, resulting in increased *spatial coherence*. We refer to spatial coherence as the alignment of sound waves in specific symmetrical patterns and the amplification of associated harmonic spectra as a result. In a similar way, present-day technologies that allow accurate spatial-geometric modelling of sound may be deployed to alter or simulate an environment and achieve a technology-enabled, spatially coherent projection of sound waves.

As wave propagation employs a path of least resistance, under the influence of harmonic resonance it provides a channel for optimal energy distribution at the associated resonant frequencies. In acoustics, such phenomena are observed as standing waves. The symmetrical distribution of wave patterns is commonly observed and studied as nodal line patterns forming on a 2-dimensional plate, known as Chladni plates named after physicist and musician Ernst Chladni, who first documented the phenomenon in 1787 [31]. The patterns are made visible by sand particles that gather at the nodes of the standing waves coinciding with the resonant modes of a vibrating plate. The study of Chladni plates remains an active field of study up until today and has been subsequently resumed and deepened throughout the 20th Century, notably by Swiss physician and naturalist Hans Jenny who popularised the phenomena and coined the term *cymatics*, from the Greek word *kymatiké* which means 'study concerning the waves'. Jenny described the aim of this research "to produce vibration models and investigate the laws to which they continually conform" [32]. Other experiments have shown that wave propagation patterns are influenced by frequency and the geometric boundary condition, size and material of the excitation medium, i.e. the vibratory medium [33-34] and propose new analytical solutions for accurate prediction of the observed patterns [35].

The ongoing research into pattern formation of sound waves also serves to demonstrate that wave propagation functions in general as an efficient distribution mechanism to deploy vibrational energy. Research suggests vibrational

patterns may determine the geometry of animal coat patterns [36] and tree formation [37], as well as show a distinct relation to repeated geometries in the formation of crystals [38] and breaking patterns of soil [39]. Mathematician and physicist J.C. Maxwell introduced the notion that the electric and magnetic field components of electromagnetic waves propagate in an orthogonal in-phase relationship. This observation coincides well with modern understanding of sound propagation as a spherical medium [40]. While Maxwell relates general wave propagation phenomena as part of the electro-magnetic spectrum (EMS), present-day research shows increasing evidence of the interconnection between sound wave propagation and related phenomena in the EMS. The frequencies of electromagnetic waves and associated photon energies were successfully coupled to harmonically relate to phonons [41]. In conjunction with this observation, ionic neuronal mechanisms were found to be intrinsically connected to accurate sound determination, hence melodic interpretation [42]. Sonoluminescence was shown to occur with precision during sound wave cycles, postulated to be equally compatible with the formation of plasma [43]. Diodes manipulating propagation of phonons were found to beneficially manage the phononic spectrum in the creation of technologies able to manipulate sound and heat [44]. Comparative study across 175 biological publications concerning the measured beneficial effects of electromagnetic waves on the state of living cells, suggests that nature employs discrete standing waves that match precisely with the acoustic harmonic scale. The identification of typical toroidal flux in phonon, photon and electron wave energies may explain functional organisation of cellular structures that enable the origination and sustainment of life processes and optimal protection against decoherence at minimal loss of energy [45].

These emerging understandings relating to general phenomena of wave propagation further demonstrate the role of harmonic resonance as a regulator of cohesive energy distribution in the *connectome* of various natural systems. We refer to the connectome as the complete network of structural links between various systems that function interdependently as one organism, synonymous with reference to the term denoting the complete network of elements and connections between the interdependent parts of the human brain [46]. In addition, we observe that systems under influence of harmonic resonance demonstrate energy moving in toroidal waves within a spherical medium [47]. The energy present within an acoustic system is optimally preserved when the energy used to produce higher harmonic states, returns back into the system with the meta-periodic resonance of each harmonic and the fundamental frequency, resulting in an overall decrease of energy dissipation across the frequency range and amplification of sound wave oscillations. Similarly, we find toroidal waves resulting from the bipolar energy flux present in magnetic fields, including the Earth's magnetic field (geomagnetic field) [48] and in the electromagnetic field of the human body (biomagnetic field) [49-50]. Notably, the human biomagnetic field is reported to increase in individuals in a natural environment or with extensive practice of methods such as Qi Gong. The enhanced biomagnetic emission could not be derived from the physical body alone as biomagnetic emission increased while its corresponding bioelectric current remained static [51].

Recognising the dependencies and similarities between sound waves, electromagnetic waves and their related phenomena supports further understanding of the as yet untapped potential for treatment and prevention of pathological conditions through acoustic means. As already shown by various studies, exposure to visual or acoustic stimuli can support and enhance healing mechanisms, stress reduction, pain endurance and general sense of well-being [52-53]. Furthermore, deploying the vibratory EMS has proven an effective means to improve various healing processes [54], including healing severe wounds [55] and eliminating destructive processes such as cancerous metastases [56]. While the notion that destructive acute processes could be reversible by presentation of stimuli may be surprising, research has shown that positive stimuli could indeed affect and reverse effects of negative stimuli, even when inherited [57].

Taking into consideration Iatrogenic diseases (disease caused by synthesized medication) were found to be the fifth leading cause of death in the world [58], this calls for new, non-invasive and sustainable methods that could employ the potential benefits of sound wave propagation for human wellbeing and health.

CONCLUSION

From the existing body of scientific research and clinical observations, we recognize sound waves as a sustainable and controllable medium to support equilibrium in various natural systems, such as enhanced homeostasis in the human body. Sound waves under the influence of harmonic resonance produce symmetrically aligned propagation patterns with distinct energy harnessing qualities, which we indicate as the spatial coherence of sound waves. The controlled projection of spatially coherent sound waves is enabled by means of new emerging spatial sound technologies and integrated mathematical constants. The immediate effects of spatially coherent projection of

sound waves on the human body have been experimentally verified, and a dependency and similarity is suggested with observed effects of related phenomena in the EMS as potential means to enhance healing processes, treat pathological conditions and reverse trauma. In particular, the potentially beneficial effect of sound waves on the human body may be viewed in the light of the fundamental role of hearing during gestation and its regulating properties in human physiology.

We hypothesize that the harmonic spectra resulting from spatially coherent sound projection can be inverted and enhanced by technology to bring upon homeostasis in natural systems, including enhanced physical and emotional wellbeing in humans. As such, spatial sound technologies may provide a means for Acoustic Effector Stimulation (AES) to help restore, maintain and optimize balance in cell organisms, implying potential application for treatment and prevention of pathological conditions associated with disease and trauma. The hypothesis may inform further studies that aim to progress the clinical methods using spatial sound for the benefit of people dealing with a wide range of physiological and psychological conditions, thereby extending upon existing practices of vibratory medicine including sound and music therapy. To further probe and establish the potential of AES as a non-invasive clinical methodology, a bottom-up design of experimental paradigms is to be concluded over the coming years, further monitoring physiological somatic response and behavioral effect ofsubjects exposed to AES, documenting the underlying acoustic and physical phenomena, aswell as providing further understanding of the governing rules of general wave propagation and its effects on various natural systems.

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GLOSSARY

Acoustic Effector Stimulation (AES)
A method of projecting sound waves on the human body that trigger effector cells to bring about physiological change resulting in enhanced homeostasis.

Acoustic Holography
A method for estimating the energy of the sound field at a source by measuring or computing acoustic parameters for an array of particles, i.e point sources, defined at or around the source emitting the sound.

Biofield (Biological-Field)
A massless field (not necessarily electromagnetic) that surrounds and permeates living bodies and affects the body. (NIH)

Coherence
The quality of being consistent and forming a unified whole. A property of a matrix describing the maximum correlation between its components. An ideal property of waves that enables stationary (i.e. temporally and spatially constant) interference (physics).

Connectome
The complete network of structural links between various systems that function interdependently as one organism. The term is generally referred to as the comprehensive map of neural connections in the brain.

Entrainment
The process whereby two interacting oscillating systems assume the same periodicity. Entrainment is a phenomenon that can be observed in physical and biological systems.

Harmonic Coherence
An oscillatory function representing a state of equilibrium in a biological system, i.e. in human physiology this condition indicates homeostasis.

Harmonic Resonance
The phenomenon where wave oscillations are increasingly amplified at a closely matching frequency and its higher harmonics, i.e. integer multiples of a fundamental frequency.

Homeostasis
Any self-regulating process by which biological systems tend to maintain stability while adjusting to conditions that are optimal for survival.

Music Therapy
An established health profession in which music is used within a therapeutic relationship to address physical, emotional, cognitive and social needs.

Resonance
The phenomenon of increased amplitude that occurs when the frequency of a periodically applied force is equal or close to a natural frequency of the system on which it acts.

Spatial Coherence
Alignment of sound waves in temporally and spatially constant symmetrical patterns and the amplification of an associated harmonic spectrum of frequencies as a result.

Syntropy (negative entropy)
A condition where organisation in the system is enhanced and energy is locally preserved and accumulates. A tendency towards energy concentration, order, organisation and life, or inversely to entropy, as a result of retrocausality leading to persistent organisation.

Vibratory Medicine (Sound Therapy)
A range of therapies in which sound vibrations are used to treat physical, emotional and cognitive needs. Vibratory Medicine uses principles of resonance and entrainment to self-regulate a system into its natural harmonic coherent state.