Effects of Geometric Sound on Human Physiology and Physical Matter: Current State and Experimental Data

Rona Geffen[1], Prof. Dr. Christoph Braun[2]
[2] Tübingen University, MEG-Center 72074 Tübingen, Germany

March 2023,✉

Key Words: #Spatial Sound #Geometric Sound #EEG #Heart Rate #Well-Being #Sound Medicine #Vibrational Medicine #Non Invasive Medicine #Stress Reduction #Relaxation #Cymatics #Faraday Waves #Brain #Connectivity Patterns #EEG power #EEG connectivity

ABSTRACT:

This study introduces Geometric Sound as a subfield of Spatial Sound by presenting auditory stimuli that are mathematically defined 3D Geometric Sound projections representing virtual sonic geometric objects. The study proposes a new and non-invasive method that might be suitable for the treatment of various illnesses of both physical and psychological nature, with emphasis on stress-related conditions and neurological impairments. The effect of Geometric Sound on human physiology and matter were investigated by brain waves, Autonomic Nervous System response, emotional well-being and Faraday waves morphology patterns. Identical sound frequencies projected in different Geometric Sound shapes were found to significantly affect brain waves topology, power amplitude and connectivity patterns compared to recorded baseline of participants where no sound was presented and stereo (control). Notably, brain waves connectivity patterns indicate a different response to identical frequencies projected in different Geometric Sound shapes. Geometric Sound was found to improve sense of relaxation and reduce feelings related to anxiousness according to behavioral response monitored by a combination of questionnaires and as measured by heart rate and blood pressure. Geometric Sound projections of identical frequencies were found to result in correlating Faraday waves patterns to the presented excitation Geometric Sound projection. We suggest Geometric Sound may have the potential to be used as a tool for the treatment of various illnesses and disabilities such as depression, anxiety, stress-related conditions and neurotrauma.

List of Figures

List of Tables

List of Abbreviations

2D	**Two Dimensional**
3D	**Three Dimensional**
ABI	**Acquired Brain Injury**
ADHD	**Attention Deficit Hyperactivity Disorder**
ANOVA	**Analysis of Variance**
ANS	**Autonomic Nervous System**
BCI	**Brain-Computer Interface**
BDI	**BECK Depression Inventory**
BPM	**Beats Per Minute**
DPSS	**Discrete Prolate Spheroidal Sequences**

EEG	**Electroencephalogram**
fMRI	**Functional Magnetic Imaging**
GLM	**General Linear Model**
GS	**Geometric Sound**
HR	**Heart Rate**
HRV	**Heart Rate Variability**
ICA	**Independent Component Analysis**
MDD	**Major Depressive Disorder**
MDMQ	**Multidimensional Mood Questionnaire**
NBS	**Network-Based Statistic**
SPL	**Sound Pressure Level**
TBI	**Traumatic Brain Injury**
TSITS	**The Sound Is the Scenery**
VCM	**Voice Coil Motor**
VR	**Virtual Reality**

INTRODUCTION:

Geometric Sound (GS) is based on mathematics and geometric constants. Our hypothesis suggests that spatial sound projections of different geometric shapes result in specific effects on humans and biological systems, attributed to the correlating projected GS shape. In order to base and verify this hypothesis on objective scientifically founded measures a line of preliminary exploratory experiments was conducted between the years 2017-2018, monitoring brain waves activity using electroencephalogram (EEG), heart rate (HR), blood pressure and behavioral response. A preliminary experiment in 2017 monitored 20 healthy young adults for their response to GS. Multiple physiological parameters such as EEG, heart rate, blood pressure and behavioral response were recorded. Results of the Autonomic Nervous System (ANS) were consistent with behavioral reports of enhanced relaxation and focus. In addition, interesting indications were shown to occur in the Alpha range. Following these results, a second experiment was conducted in 2018 monitoring 30 young adults. The motivation for the second experiment was to verify the EEG results, study brain waves connectivity patterns, as well as test additional GS shapes on a larger group. This experiment focused on behavioral response and EEG recordings. In addition to the first study, EEG was further analyzed for topographical changes in power and connectivity patterns. The study originated from an artistic-scientific project titled The Sound Is The Scenery (TSITS) which investigated the connection between sound, geometry and mathematics with healing and well-being by placing people inside geometric structures of spatial sound and light [1].

This study is interdisciplinary by nature and based in different fields - It is rooted in sound via sound medicine and spatial sound technology, incorporates mathematics and geometry, and is inherently related to biology and neuroscience. Following, a background introduction is provided to the different fields informing this study.

Current State Background and Literature Review:

Spatial Sound and Cymascope Technology:

Spatial Sound is an emerging immersive technology enabling precise sound localization and movement notation that facilitates enhanced multidirectional sound experience and projection of audio holograms, providing a 360-degree field sonic experience. In the field of spatial sound 4DSOUND [2] is a leading technology integrating hardware and software systems to provide fully omnidirectional sound environments which enable vivid sonic experience, as well as advanced sound conception and computation. The effect of immersion provided by spatial sound systems exceeds the commonly known experience of listening, as it allows the entire body to be enclosed by directed sound vibrations. Notably, unlike the common perception of sound as a 2D waveform medium, it is in fact a spatial medium, spherical in shape and ever expanding [3]. Its spherical form contains a multiplicity of waves and their equivalent particle trajectories which generate a toroidal energetic flow within each sonically excited molecule. The holographic nature and principle of sound was suggested following experiments and measurements conducted with the Cymascope instrument [4]. The Cymascope instrument makes sound visible by transforming audio input periodicities to water wavelet periodicities, the latter known as Faraday Waves or cymatic phenomena.

Geometry and Mathematics as a Form of Natural Coherency with Fundamental Relation to Sound:

Geometric structures and numeric sequences appear in nature as functional distribution frameworks. Examples include Fibonacci sequence at the basis of nucleotide frequencies of appearance in human genome [5], the geometric basis of atomic structure of chemical elements [6], the relation between prime numbers and atomic structure in crystal-like materials [7], toroidal coupling of phonon, photon and electron information to mediate physical and emotional biological processes [8] and crystallization processes [9]. Research suggests that water crystals tend to form in hexagonal structures when exposed to coherent stimuli as opposed to a chaotic structure when exposed to incoherent stimuli [10, 11].

Mathematical sequences such as the Fibonacci sequence are widely present in growth algorithms in nature and harmonic ratios and are maintained in general natural phenomena [12], for example various flora constants [13], limbic and facial symmetries and constructions [14]. It is assumed by researchers that growth and alignment patterns in this sequence adhere strength and efficiency [13, 15]. The "Golden Ratio", or Phi, which is easily derived from Fibonacci numbers and Fibonacci like sequences is closely related to the construction of geometry [16] fractal geometry, coherent and cohesive energy distribution and symmetry, and was found to exist at the quantum level in magnetic resonance of atoms [17] and in Red Blood Cells (RBC) discoid structure [18]. These mathematical constants allow similar geometric patterns to repeat on a range of scales in nature, for example pentagonal and hexagonal structures ranging from DNA molecule binding [19, 20] to planetary trajectories [21].

Sound is inherently related to geometry and mathematics with ordered symmetry of standing waves and their related mathematical ratios. Similar ratio patterns as those in the harmonic ratios of an octave have been found in various natural phenomena, such as the periodic table [22-7], planetary relations [23], colors [24], and brain waves [25]. An important example of how coherency is expressed in a geometric manner in nature is the propagation of sound waves, known as Chladni figures in its 2D expression [26], and Faraday Waves or Cymatics in its 3D expression [27-29]. Matter excited by sound frequencies can be visualized by vibrational morphology patterns in the form of symmetrical geometries. The patterns are known to be determined primarily by frequency, amplitude and boundary condition of the observed medium [30]. This phenomenon demonstrates the harmonic overlaying of sound frequencies and their relation to geometry and mathematics. A study by Reid et al. used Faraday waves to diagnose and differentiate cancer cells from healthy cells in brain tissue. The study effectively demonstrates that healthy cells generate continuous symmetrical patterns while cancerous cells are prone to generate more chaotic patterns [31]. In relation to self-biofeedback to support learning and self-regulation processes, it is interesting to note that sound researcher Hans Jenny was able to teach deaf children to better speak and improve their pronunciation by having them look at the cymatic patterns emerging from their own voice, hence seeing the dissonances in false pronunciation and the symmetry created by correct pronunciation [27].

These examples show a distinct correlation of geometric symmetry with coherency and effectively form the foundation of the present study in which a geometric feedback loop is employed to impose and entrain natural systems into coherency.

Sound and Music as Medicinal Modalities:

Music was found to be beneficial to improve healing processes [32], relieve stress, depression and anxiety [33-35], affect mood [36,37], energy and physical state [38,39], enhance longevity of blood cells [40] and ignite brain functioning supporting hearing mechanisms which could be described as enhanced structural and cellular reaction [41]. Nowadays, the use of music therapy in hospitals and schools is increasingly growing across countries and cultures [42-46]. As our society becomes more accustomed to the use of music as a healing modality, the use of sound in this context is relatively new to western societies. However, sound medicine, also known as sound therapy or sound healing, is an ancient practice used throughout history in different cultures around the world to relieve physical pain and emotional turmoil [47, 48]. Sound medicine incorporates the use of sounds such as the human voice, nature sounds and various instruments including tuning forks, singing bowls, gongs and drums - all providing sound that is rich in frequencies and overtones. The natural mechanisms on which sound medicine relies upon are entrainment and resonance coherence of frequencies and rhythms. Notably, sound is rhythmic by definition as each frequency is derived from its vibrational oscillation. Music and sound medicine modalities were found to ignite physiological and psychological responses such as beneficial hormone secretion [49], synchronization of brain waves to beats and binaural beats [50-52], improvement in symptoms of neurotrauma brain impairment [53-56] and induction of stress and pain relief mechanisms [38-57].

Although it is often assumed that sound is perceived only by our ears, its fundamental vibratory rhythmic pulsation or subtle mechanical pressure is perceived by our skin, bones, internal organs and cells [58]. Furthermore, natural living systems emit sound as part of their functional mechanism as well as depend on sound for healthy systemic maintenance. Commonly known examples include the sound of our breath, heart and nervous system. Additional examples show that cocooned butterflies produce sound as part of their mechanical oscillation metamorphosis [59], plants are affected by sound as they grow [60, 61], sound of a healthy coral system supports the rehabilitation processes of dead corals [62], cells were reported to emit audible sound and react with high pitched sound when agitated by toxic substances [63]. These examples demonstrate the core theme leading sound medicine of sequenced entrainment and revival of physiologic mechanical processes. Notably, while the use of such practices to affect health could be disregarded as alternative medicine there is solid scientific evidence confirming natural enhancements are as beneficial, and sometimes more beneficial than synthesized medications [64-67].

While growing in scope, there's only very little scientific research on the physiological effects of sound medicine. In addition, most studies that explored the effects of sound medicine focused on behavioral evidence. For example, Goldsby, et al. [68] reported the effects of sound meditation on mood, anxiety, pain and spiritual well-being. Following sound meditation participants reported significantly less tension, anger, fatigue, and depressed mood, while feeling of spiritual well-being significantly increased. Another research by Cooper et al. [69] explored the effect of sound meditation and shows statistically significant effects of physical relaxation, imagery, ineffability, positive mood, insightfulness, disembodiment and unity across both live and recorded sessions. Fewer studies have addressed the physiological basis of sound medicine; a study by Ito et al. [70] examined the effect of high-resolution audio music box with positive hypersonic effects on brain waves, as recorded using EEG. Results indicate that high-resolution audio music box sound has the effect of increasing vigilance and relaxation of the brain. In addition there is accumulating evidence of the physiological effects of relaxation therapy practices other than sound medicine, including mindfulness [71], meditation [72] and music therapy [73], as recorded by EEG [74-76] Functional Magnetic Imaging (fMRI) [77-78] and Heart Rate Variability (HRV) [81, 82].

While the use of technology in mindfulness and meditation practices is growing in scope, sound medicine is commonly conducted in private or group sessions and the use of technology, including advanced sound technology, is rarely considered. This study proposes a method using spatial sound technology in combination with sound medicine in order to induce positive physical and emotional effects.

Medical and Neurologic Background of Music Interventions:

Research have found that stress and anxiety could negatively affect well-being and increase vulnerability to disease, including autoimmune disease and inflammatory processes [83-86] acute pain [87-89], various skin conditions [90], reproductive system failure [91-93], cardiovascular disease [94, 95], respiratory system failure [96-98], dysfunction in muscular dystrophy [99, 100], bone depletion [101], immune system deficiency [102], eruption of psychological conditions [86, 103, 104], premature and enhanced aging symptoms [105-107].

When modeling neurotrauma, whether caused by Acquired Brain Injury (ABI) or Traumatic Brain Injury (TBI), it is common to see structural impairments in brain regions. Some non-invasive approaches have been in use - for example, conditions of neurotrauma were shown to improve functionality following neurofeedback processes and practice, to the point that brain modeling had changed in conjunction with improved capabilities [108]. Post neurofeedback modeling scans support behavioral and functional results and neurofeedback is increasingly used and accepted as liable treatment to various conditions including more mundane ones such as ADHD [67]. Such results imply that brain plasticity holds an important role in neurotrauma recovery processes and could benefit restitution of neurotrauma destructive influences [54-56]. Biomedical theories suggest that sound and music encourage neuroplasticity and that neurophysiological processes may be activated by music stimulation. Sound and music analysis are biological processes, prone to engage different cortical regions and therefore could enhance plasticity within and between networks, including neighboring regions to the auditory cortex [109]. Music interventions post ABI and TBI were found to positively affect brain connectivity and mechanical function such as gait and coordination, improve social skills, communication and well-being, improve mood disorders such as depression and irritability and improve general quality of life [55,56][110-113]. Similar significant results between live and recorded music intervention sessions were reported following TBI on agitation and post traumatic amnesia [110]. Further, music was found to have substantial functional effect on neuroplasticity in resting-state networks after moderate to severe TBI. Martinez-Molina et al. reports within and between network connectivity changes in cognitive networks, increased connectivity between frontal and parietal regions, enhanced executive function, increased gray matter volume in right inferior frontal gyrus, increased coupling between rsFC in the frontoparietal and dorsal attention which are associated with TBI related cognitive impairments, as well as between these networks and primary sensory networks. A shift towards decreased connectivity in networks typically hyperconnected following TBI was also reported [55]. Importantly, no harmful results were reported across various types of music interventions and studies [55, 110-114].

This study suggests a non-invasive treatment for various stress related and brain impairment conditions using sound and mathematical bio-feedback processes as a medicinal practice. The method at hand uses spatial sound technology and could support healing processes as it was found to effectively reduce stress and advance relaxation among participants in a short time. Another application of this study provides a non-invasive method to treat conditions of neurotrauma.

MATERIALS AND METHODS:

We investigated the effects of GS on physiological parameters as recorded by EEG and measures of the ANS monitoring blood pressure and HR in conjunction with behavioral measurements as analyzed from standard and custom questionnaires. Experiments were conducted as within group comparisons and all participants were exposed to all types of sound stimuli. Two separate experiments were conducted monitoring an overall of 50 participants. The first experiment in 2017 (E1) monitored 20 participants listening to Sphere GS shape and 10 participants also listening to Pyramid GS shape. The second experiment in 2018 (E2) monitored 30 participants listening to Pyramid, Cube and Sphere GS shapes. Across both experiments all participants were monitored for Base and Stereo (control) conditions. All sound stimuli were monitored for an epoch of 5 minutes each. All measurements were taken while participants were comfortably seated with eyes closed. Participants were enclosed in the GS virtual shapes projections, sitting in the center of the shapes at their base vertical level. The order of sound stimuli randomly alternated between participants and was recorded on a double blind paradigm. The study was approved by the ethics committee of the Medical Faculty of Tübingen University. Both E1 and E2 were conducted on 4DSOUND at MONOM Center for Spatial Sound, Berlin.

Participants:

A total of 50 participants were monitored in E1 and E2, of which 22 female and 28 male, mean age 26.

In E1 20 participants were monitored (8 Female and 12 male, mean age 26). In E2 30 participants were monitored (14 female and 16 male, mean age 26). All participants were young adults (20-40) and signed an informed consent and waiver form prior to enrolling in the study. Subjects declared not to suffer from any mental or health issues to their awareness and were not taking any medication regularly. Subjects were instructed to sit with eyes closed for the entire experimental paradigm. Recruitment was conducted via an open call on social media, a random group of people was chosen from all applicants. The preferred research group for this preliminary study was healthy young adults in order to demonstrate possible effect on mundane situations as well as establish and validate baseline indication for safety of the method prior to possible studies on designated populations with more acute conditions.

Sound Stimuli:

The study centered on one interval of an octave between the frequencies 272.2 Hz and 544.4 Hz played simultaneously. The frequencies were produced by unweighted tuning forks manufactured by Acutonics [115]. These tuning forks are used in sound medicine practice to induce a sense of grounding, relaxation and improved sense of well-being. The sound sample used for the sound stimuli was recorded and then looped and projected in mathematically defined structures of GS and stereo positioning (control). The exact same sound sample was used in all GS and control. Each sound stimulus was played for an epoch of 5 minutes. All samples were played on 4DSOUND using a spatial configuration of 48 omnidirectional loudspeakers placed above, below and around the subjects. All sound stimuli were played on the same output volume. Acoustic output level was adjusted to project the same sound pressure level (SPL), loudness and volume ensuring none of the GS shapes or control was perceived louder to the listening subjects. Control sound stimulus was played in the same configuration as all GS shapes and according to the same sound projection characteristics. All sound stimuli were projected and recorded at <85db. Presentation and order of sound stimuli randomly alternated between participants. The sound stimuli monitored were:

0. Five minutes No Sound (Base condition)
1. Five minutes Stereo sound (Control)
2. Five minutes Pyramid GS
3. Five minutes Cube GS
4. Five minutes Sphere GS

Max dBA levels in dBFS of the presented stimuli are available via the following link Appendix 1.

Geometric Sound Shapes:

All GS and stereo positioning were constructed in the same ratio with the same diameter and played on the same speaker configuration space. All shapes were constructed in relation to each other, for instance the length of the square L in Cube GS is identical to the length of the Pyramid base, all shapes are constructed with the same diameter.

The calculations for the shapes are as follows:

Pyramid:

The Pyramid is based on the (inverse) Golden Ratio (ratio = 1/ 0:618=1.618), which dictates its ratio and hence steepness. Pyramid Base Length: L= 8 m. Height Pyramid: H= ratio * L = 4,944 m. The Pyramid was decomposed into three (square) horizontal slices, from its base to its top (point) via an intermediary level, with the following coordinates:

1. Base: L1 = 8 m center is situated at (0,0,0)

2. Intermediary: L2 = 4,944 m center is situated at (0,0,1.889)

3. Top: L3 = 0 m, y3 = 4,944 m center is situated at (0,0,4.944)

Cube:

Sides of Cube = 8 m centered in space.

Sphere:

The Sphere is defined according to a ratio, such that the cube and the pyramide are inscribed in a sphere. The diameter D of the Sphere is computed according to the base length L of the Cube and the Pyramid:

D = (1+ 0.273) * L = 10.184 m

Sound Environment:

Experiments were conducted on 4DSOUND system at MONOM Center for Spatial Sound Berlin. The 57 channels 4DSOUND setup in MONOM studio consists of 48 omnidirectional satellite Bloomline Acoustics OmniDrive Pro Mark II speakers in a 4 x 3 x 4 equally spaced grid, combined with 9 Bloomline Acoustics 4D OmniSub (Custom) subwoofers. The available spatialisation surface dimensions are 12 m x 12 m, and 4 m in height. In combination with the proprietary 4DSOUND software algorithms, this three-dimensional speaker configuration produces high definition sound spatialisation. The frequency range is 20 Hz to 20 kHz, and acoustic dynamics up to 116 dB. The sound output of each loudspeaker was determined by a computer-generated rated sound field consisting of virtual point-specific audio components and a panning algorithm using the 4DSOUND v1.3 software.

Cymascope:

A stereo recording from the center of the GS shapes, where participants were placed, was recorded using Zoom H4n Pro with an angle of 120 degrees under the same sound projection conditions. All recordings were conducted at the same location under the same conditions as E1 and E2. The recordings were then sent to Cymascope laboratory in a stereo 24Bit, 48,000HR Wave format for analysis. Within the Cymascope instrument, the fused-quartz water-filled cuvette is direct-coupled to a Voice Coil Motor (VCM) with vertically driven piston. Electronic filtering is applied in the signal path to ensure that resonances, inherent in the VCM-cuvette assembly, are negated, resulting in a flat response characteristic curve. All samples were observed via direct ocular viewing, then photographed using a Canon EOS 5D Mark camera and analyzed under the same conditions. The sound stimuli samples as recorded and analyzed by the Cymascope instrument, are available via the following link Appendix 1.

EEG:

Data recording:

In E1 data was collected and analyzed by neuroscientists from the BioKeshev Institute (IL) (Figure 1).

In E2 data was collected by neuroscientists from the Institut für EEG-Neurofeedback and the Peak Brain Institute (DE). In E2, spectral and functional connectivity analysis as well as the statistical analysis of EEG results was conducted at the MEG-Center, University of Tübingen (DE). Both in E1 and E2 participants' EEG was recorded in the standard 10/20 system. EEG was recorded continuously with a sampling rate of 256 Hz and an antialiasing lowpass filter set to 64 Hz. Each sound stimuli was monitored for 5 minutes. In E1 the last minute of each epoch was analyzed and participants with noisy artifacts were removed from the analysis paradigm, for technical reasons only 10 participants were monitored for Pyramid GS condition. In E2 subjects with noisy artifacts were removed from the analysis paradigm of brain waves power amplitude. For the connectivity analysis, segmented data of 500 ms duration each were visually inspected and epoques contaminated by artifacts were discarded. Using this procedure all subjects could be considered for the brain connectivity analysis. Analysis methods varied according to the customs of the team analyzing them.

Figure 1: E1 EEG measurements by Dr. Anat Barnea from the BioKeshev Institute at MONOM Center for Spatial Sound Berlin. The omnidirectional speakers are placed in the observed black columns. Each column holds 3 speakers: at ground level, top (4 m) and middle.

Spectral Power and Connectivity analysis

Investigating the functional connectivity of brain activity by means of coherency, EEG data were analyzed using MATLAB (MathWorks Inc., Natick, Massachusetts USA), NBS Connectome [116], and FieldTrip, an open-source MATLAB toolbox specifically developed for the analysis of electrophysiological data [117].

After offset removal and high-pass filtering of the EEG data at 1 Hz data were segmented in junks of 500 ms. Eye and heart artifacts were removed using an Independent Component Analysis (ICA). In the subsequent frequency analysis a multitaper approach, with Discrete Prolate Spheroidal Sequences (DPSS) as tapers with a smoothing window of ±4 Hz was used. The Fourier spectrum of the signal was determined, selecting for frequencies ranging from 2 to 64 Hz, in steps of 2 Hz. The power in the Delta (1-4 Hz), Theta (5-8 Hz), Alpha (9-13 Hz), Beta-1 (14-20 Hz), Beta-2 (21-35 Hz), Gamma-1 (36-48 Hz) and Gamma-2 (52-75 Hz) frequency band were calculated by averaging the power across frequency bins. To test the statistical significance of the differences in power topography between the different geometric sound types and the Base condition cluster-based permutation statistics was used. By averaging the power across electrodes, a global power estimate was obtained for each GS type and each frequency band. Statistical differences were obtained by subjecting the global power values to repeated measures ANOVA. Connectivity analysis was performed on n trials at the sensor level, using the absolute part of imaginary coherency as measure of functional connectivity.

$$c = \left| Imag\left(\frac{\sum_n F_{ik}(f) F^*_{jk}(f)}{\sqrt{\sum_n F_{ik}(f) F^*_{ik}(f) \sum_n F_{jk}(f) F^*_{jk}(f)}} \right) \right| \quad (1)$$

With $\sum_n F_{ik}(f) F^*_{jk}(f)$ and $\sum_n F_{ik}(f) F^*_{ik}(f)$ being the cross and the auto spectra, respectively, of the EEG activity $F_{ik}(f)$ recorded in trial k at channel i and j. The absolute part of the imaginary part of coherency ($I(.)$) was chosen in order to avoid spurious connectivities due to the spreading of the signal to neighboring electrodes [118]. Given the electrodes, the output of the connectivity analysis was a $n\,x\,n$ connectivity matrix (19 x 19), quantifying the level of interaction between all pairs of EEG sensors.

Network statistical analysis

NBS connectome [116] has been used to perform network statistical analyses, applying the cluster-based nonparametric method implemented in the Network Based Statistic (NBS) software [116]. A Non-parametric way of testing was chosen due to the non-normally distributed values of coherency. The cluster-based approach was chosen to avoid exhaustive multiple testing. Connectivity matrices were used as input for the analysis. For the statistical analyses in NBS, design matrices and contrast vectors were defined in terms of a General Linear Model (GLM).

The Network-Based Statistic method involved four different steps. First, it runs a massive univariate test to define a test statistic value for each connection. Second, it compares the t-statistic of each connection, with the previously defined threshold set to t>3.1 in order to identify all supra-threshold connections. Then the presence of any topological clusters among the sets of supra-threshold connections are selected. To this end significant connections that shared common nodes were summarized in individual clusters. Finally, to run a second level statistical testing comparing the differences of connectivity patterns across conditions, connectivity data of individual subjects were randomly assigned to the conditions to be compared. A total of 5000 permutations was performed in each permutation t. The size of the largest cluster, expressed in a one-sided FWER-corrected p-value [119], is recorded. Permutations provide an empirical null distribution for the size of the largest cluster. For the statistical analysis pairwise comparisons between conditions were carried out.

Behavioral Response and Questionnaires:

In E1 all participants were required to answer BECK Depression Inventory (BDI) before enrolling in the experiment. Participants also answered a custom questionnaire composed by the researcher, to monitor their well-being and emotional response before and immediately after enrolling in the experiment (To view the full custom questionnaire please see Appendix 2). In E2 participants were required to answer the

Multidimensional Mood Questionnaire (MDMQ) and the same custom questionnaire as in E1 before and immediately after enrolling in the experiment. BECK and the MDMQ are verified questionnaires and the custom questionnaire provided additional indication on the effect of the stimuli on participants without impinging the procedure. All questionnaires were administered in the same order both before and after the experiment.

Both in E1 and E2 participants were given the option to provide additional written and video recorded testimonials of their experience. Statistical analysis of results of all questionnaires both in E1 and E2 was conducted on SPSS 25.0 using paired t test. Statistics were conducted for each experiment separately and the average response to both experiments was also computed. Not all items were filled in by all participants thus some were disqualified from being considered for the statistical analysis of results.

Blood Pressure and Heart Rate:

20 participants in E1 were monitored by a trained nurse for their Blood Pressure and HR immediately after each epoch of sound stimulus. Blood Pressure and HR were also monitored for Base condition. For technical reasons only 10 participants were monitored before and after exposure to Pyramid GS.

RESULTS:

Physiological Response - Brain Waves (E1, E2):

Both in E1 and E2 a significant decrease in Alpha activity is observed between base condition and Stereo, further decrease is observed between Stereo and all GS shapes projections (Figure 2A, 2B). In both experiments Pyramid is showing the lowest Alpha activity. In E2 most significant results of Alpha decrease are obtained between Base, Pyramid and Cube conditions (Table 1). In E2 which measured more GS shapes, brain waves power amplitude at different frequency bands show varying activity patterns between the sound stimuli. Beta2 is significantly affected by all GS and not control (stereo). Gamma is significantly affected only while exposed to Pyramid GS (Table 2).

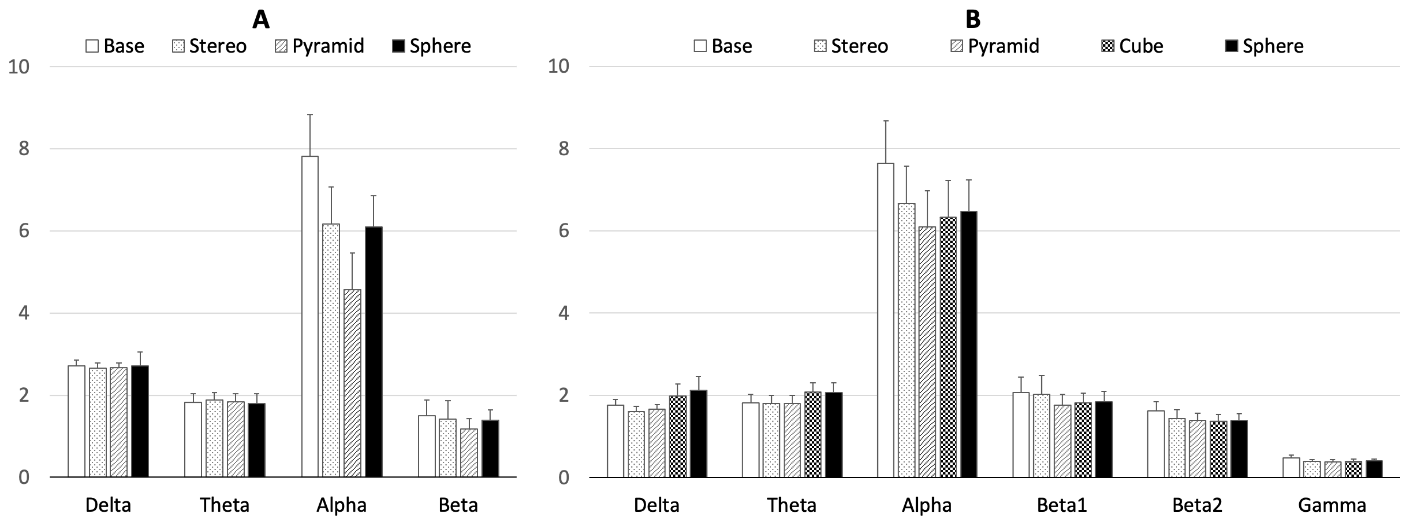


Figure 2: EEG-Power in the Delta, Theta, Alpha and Beta frequency range. Error bars represent the standard error of the mean. **Figure 2A: E1 EEG power amplitude values (N=16), Figure 2B: E2 EEG power amplitude values (N=28)**

Effect	**F**	**df**	**p**
Baseline – Stereo (control)	3.814	1,27	0.061
Baseline – Pyramid	13.052	1,27	**0.001**
Baseline – Cube	5.856	1,27	**0.023**
Baseline – Sphere	3.876	1,27	0.059

Table 1: E2 Decrease in Alpha activity compared to base condition (N=28).
Alpha decreases in all sound stimuli compared to base condition. Pyramid condition shows the most significant results of Alpha decrease. Both Pyramid and Cube present a significant Alpha activity decrease. Baseline-Stereo $p \leq 0.061$; Baseline-Pyramid $p \leq 0.001$; Baseline-Cube $p \leq 0.023$; Baseline-Sphere $p \leq 0.059$.

Effect	**F**	**df**	**p**
BETA 2			
Baseline – Pyramid	7.858	1,27	**0.009**
Baseline – Cube	5.855	1,27	**0.023**
Baseline – Sphere	4.764	1,27	**0.038**
GAMMA			
Baseline – Pyramid	8.113	1,27	**0.008**

Table 2: E2 Significant activity patterns between all tasks in Beta2 and Gamma bands (N=28).
Beta 2: Baseline-Pyramid $p \leq 0.009$; Baseline-Cube $p \leq 0.023$; Baseline-Sphere $p \leq 0.038$
Gamma**:** Baseline-Pyramid $p \leq 0.008$

These results indicate significantly different activity patterns in the power amplitude of Alpha, Beta2 and Gamma brain waves. This indication is identified between Base (no sound) and all sound stimuli, between control (stereo) and all GS shapes, and between the different GS shapes (Table 1-2). The topology of the power amplitude analysis further elaborates on these results. Differential significant changes are observed in all GS projections compared to Base condition. In the Alpha band, Sphere, Cube and Pyramid GS result in symmetric topography compared to Base condition, control (stereo) does not result in a symmetric topography. Significant changes are also observed at the Beta and Gamma bands, mainly in the left and central regions; these changes occur only in all GS projections and not in control compared to Base condition and mainly in Pyramid and Cube GS. Analysis shows significant changes in the different frequency bands mainly in the left hemisphere. Symmetry is not present in the higher bands where topological effect is present mostly in the left hemisphere. Pyramid is showing the most significant topological activity along the widest frequency range among all GS shapes (Figure 3).

The results are further demonstrated in connectivity patterns. E2 EEG recordings were further analyzed for connectivity patterns and topology. The results emphasize the trend observed in brain wave power amplitude patterns between GS and control. The analysis shows identical sound frequency samples result in different connectivity patterns during exposure to each GS shape. Results are inline with Faraday waves cymatic analysis observations and indicate that each GS shape creates specific connectivity patterns between brain regions. Concentrating on statistically significant connectivity clusters only, different connectivity patterns are observed between Base condition (no sound) and all GS shapes, between control (stereo) and all GS shapes and in comparison between some of the GS shapes. The frequency interval that was measured showed significant activity in connectivity patterns in the Alpha range mostly at 12 Hz (Figure 4A). As values of power amplitude decrease in the Alpha range in all projections, (statistically significantly in Pyramid and Cube GS, and close to significance in Sphere and control) the increase of connectivity patterns is independent from power and thus a significant result. At 12 Hz different connectivity patterns are observed in all sound stimuli and are more present in the left hemisphere, especially in the frontal left lobe (Figure 4A). Significantly different connectivity patterns are observed in Pyramid GS compared to Base condition in the frequency range between 10 Hz and 16 Hz.

Each band shows different connectivity patterns between different GS projections. Different patterns were also observed in Cube GS at 16 Hz (Figure 4A). Furthermore, significant differences are found between the sound stimuli - between Sphere and Pyramid GS at 8 Hz and between Cube GS and Stereo at 12 Hz (Figure 4B). Other significant connectivity patterns are observed at more sephoradic frequencies in the Beta and Gamma bands, for more information on the different frequencies and connectivity patterns please see Appendix 3. Notably, results on all activity measures - topologic power amplitude and connectivity patterns are consistent over analysis paradigms with respect to larger effect of GS compared to control (stereo) and predominantly in the Alpha band.

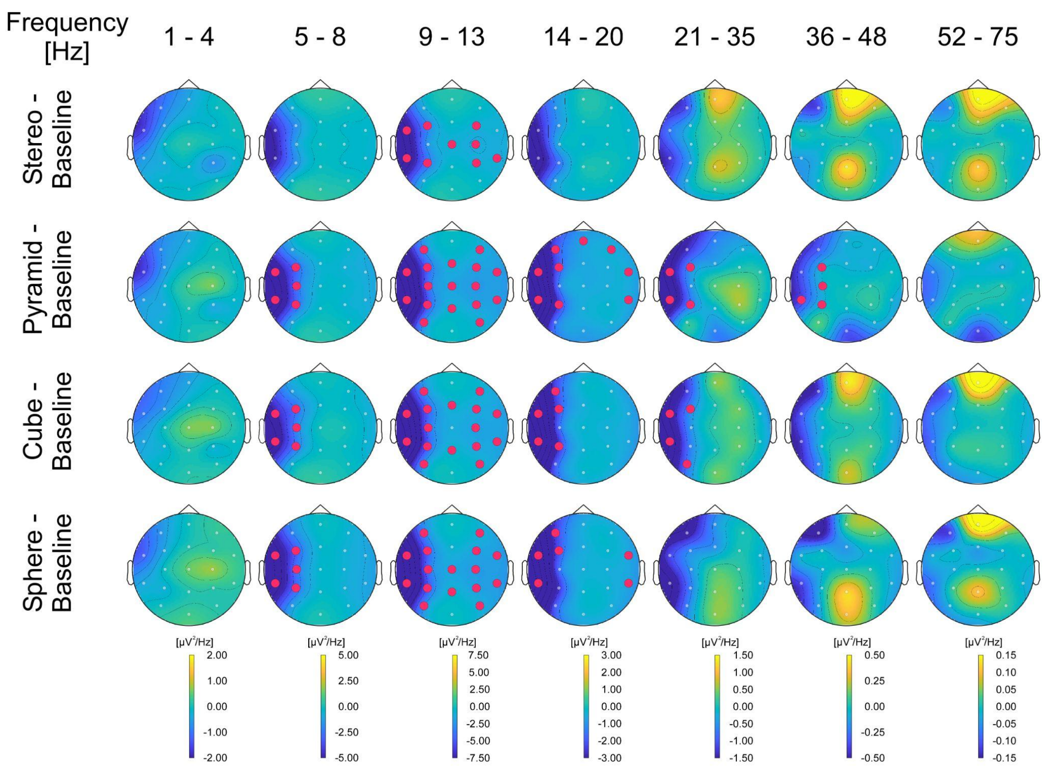


Figure 3: Significant results of topological analysis. Red spots are showing areas of significant change in activity in the Alpha, Beta and Gamma bands during exposure to different stimuli compared to baseline (N=30)

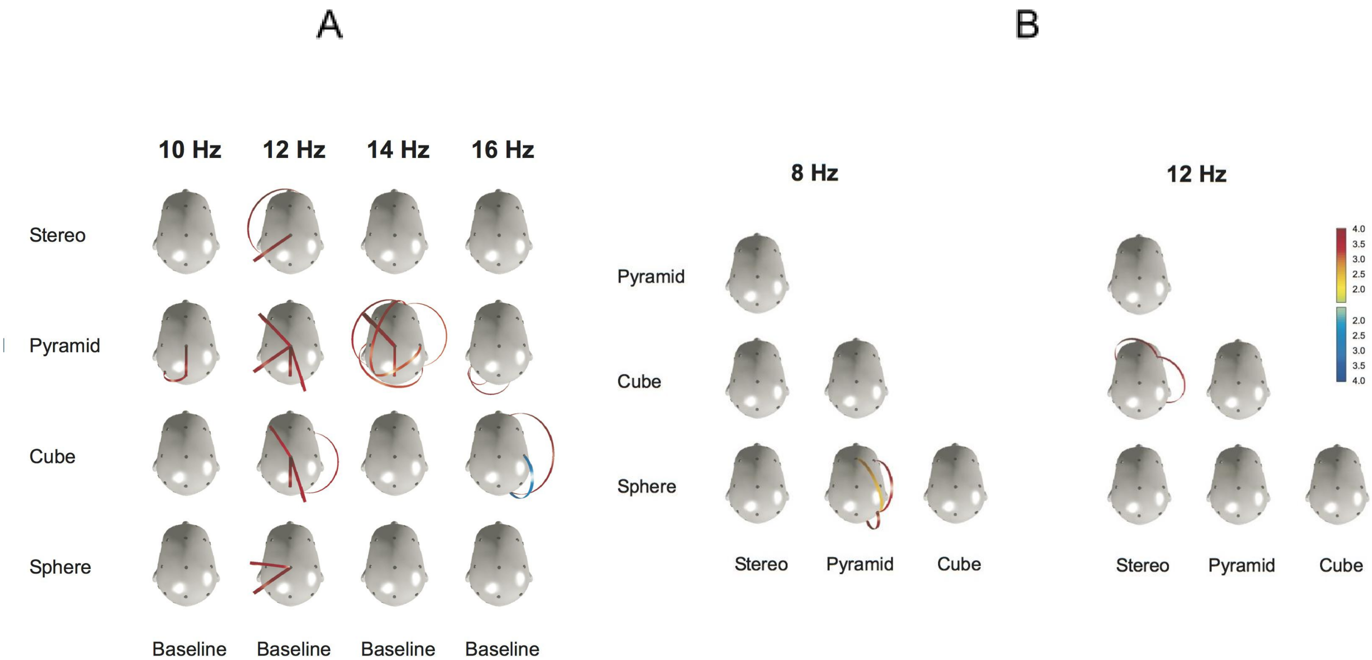


Figure 4: Significant results of connectivity patterns. Figure 4A: Significant results of different connectivity patterns at 12Hz area between base condition, GS shapes (Pyramid, Cube, Sphere) and stereo (control). Red lines indicate statistically significant results of enhanced connectivity in exposure to sound; Blue lines indicate statistically significant results of enhanced connectivity in base condition. Different connectivity patterns are observed mostly with Pyramid condition in the range between 10 Hz - 16 Hz (N=30). **Figure 4B: Significant results of connectivity patterns between all sound stimuli.** GS shapes Sphere-Pyramid at 8Hz and Cube-Stereo at 12 Hz (N=30)

Behavioral Response:

In E1 and E2 effects of exposure to the sound stimuli were monitored by a combination of questionnaires. The results from all questionnaires show a clear tendency towards improved sense of well-being, enhanced positive feelings and decreased negative feelings. Quantitative results are presented in the figure legend of respective graphs (Figure 5A-C, 6).

Behavioral Response - Custom Questionnaire (E1, E2):

Significant results in E1 were obtained in enhanced sense of relaxation and physical sense and reduced sense of fear and frustration (Figure 5A).

Significant results in E2 were obtained in enhanced sense of relaxation, happiness and confidence and reduced sense of fear and frustration (Figure 5B).

An average of results from both experiments was also computed and shows significant results in enhanced sense of relaxation, happiness and confidence and reduced sense of fear, depression and frustration (Figure 5C).

Notably, the positive trend towards improved general well-being is maintained in items that did not generate significant statistical results.

Behavioral Response - MDMQ (E2):

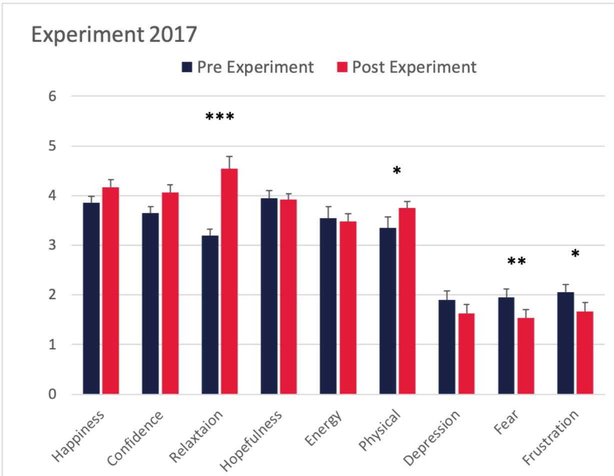
MDMQ results show significant improvement in items: Rested, Relaxed, Deeply Relaxed, Restless, Bad, Worn Out, Uneasy, Unhappy, Nervous. Most significant results were achieved for Deeply Relaxed, bad and Nervous items (Figure 6).

Behavioral Response - Experiential Testimonials of Participants (E1, E2):

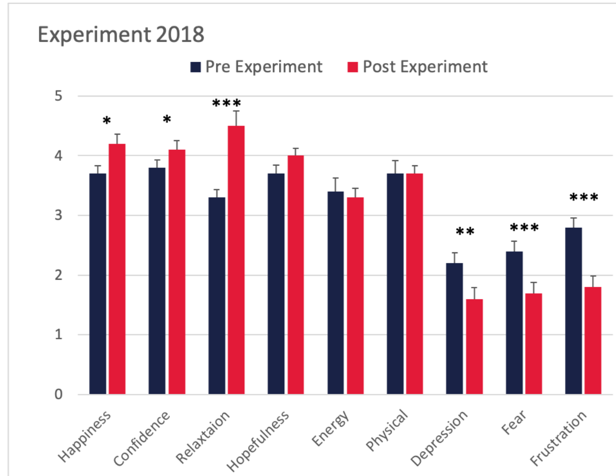
Participants were given the option to elaborate on all items in the custom questionnaire and provide free testimonials on their experience. The testimonials are inline with quantitative replies collected over the MDMQ and custom questionnaires. 95.8 % of participants, an absolute majority, reported the overall experience was positive, uplifting and beneficial. Participants pointed out a combination of positive sensations such as a sense of deep relaxation, enhanced sense of focus, improved sense of self esteem, confidence, calmness, hopefulness, and vitality, improved sense of physical feeling, enhanced imagery including elaborated images, colors and memories. Participants also largely refer to a feeling or sensation similar to meditation. Some examples of quotes from participants include: *"I feel happy and relaxed, much calmer after than before", "Noticeable less agitated by everything", "I feel more relieved, also physically and possibly more elastic", "Sounds helped me calm and see the good rather than the bad".*

(For a full list of replies please see Appendix 4)

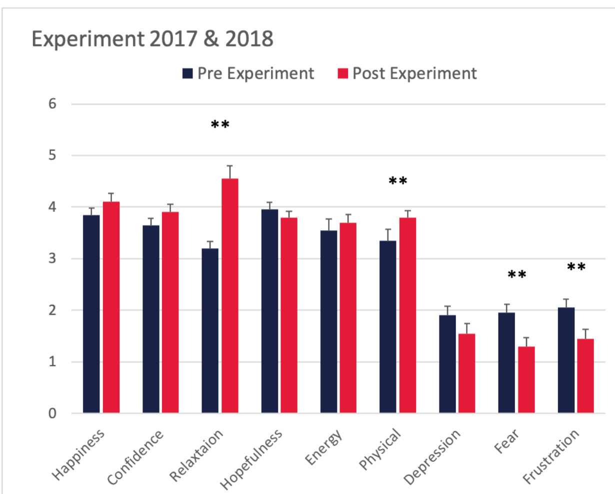
5A



5B



5C



6

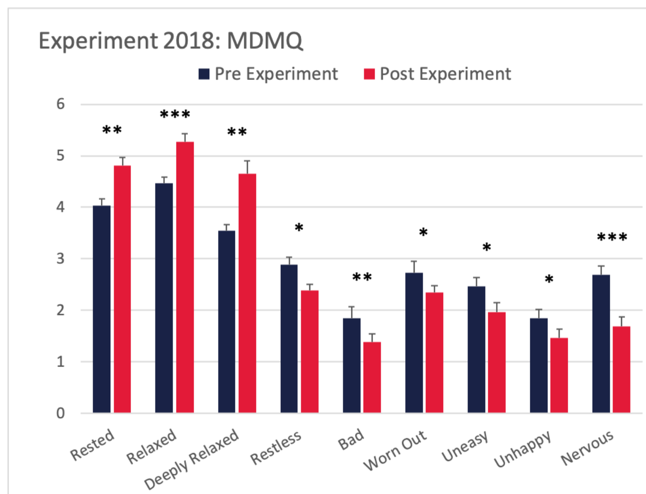


Figure 5. Statistically significant results to custom questionnaires. Figure 5A: E1 Statistically significant results to custom questionnaire, (N=20). Relaxation p≤0.001, Physical p≤0.025, Fear p≤0.008, Frustration p≤0.014. (significance level .01 <p<.05; **: 0.001<p<=0.01; *:p<0.001). **Figure 5B: E2 Statistically significant results to custom questionnaire, (N=28).** Happiness p≤0.011, Confidence p≤0.015, Relaxation p≤0.001, Depression p≤0.007, Fear p≤0.001, Frustration p≤0.001 (significance level .01 <p<.05; **: 0.001<p<=0.01; *:p<0.001)**. Figure 5C: E1 and E2 statistically significant results to the custom questionnaire, (N=48)**. Happiness p≤0.004, Confidence p≤0.002, Depression p≤0.002, Fear p≤0.001, Relaxation p≤0.001, Frustration p≤0.001 (significance level .01 <p<.05; **: 0.001<p<=0.01; *:p<0.001). **Figure 6: E2 Statistically significant results to MDMQ questionnaire, (N=26).** Rested p≤0.002, Relaxed p≤0.001, Deeply Relaxed p≤0.001, Restless p≤0.045, Bad p≤0.001, Worn Out p≤0.030, Uneasy p≤0.025, Unhappy p≤0.048, nervous p≤0.001 (significance level .01 <p<.05; **: 0.001<p<=0.01; *:p<0.001.

Physiological Response - Heart Rate and Blood Pressure (E1):

HR and blood pressure of all 20 participants in E1 was monitored before and after exposure to Sphere GS and Stereo (control).

Heart Rate:

General HR between all participants decreased during the experiment from an average of 73 beats per minute (BPM) at base condition to average 69 BPM after both stereo and Sphere GS, and average 67 BPM after Pyramid GS. A closer look and computation of average results for male and female participants shows a distinct pattern of relaxation after immersion in GS (Table 3). Results show a tendency towards relaxation as well as suggest different physical reactions to GS in comparison to the control condition. Results of male participants in particular show enhanced reaction to GS compared to control. Average HR among male participants was 72.7 BPM in base condition and 70.1 BPM after exposure to Stereo (control). Both are considered within the range of average HR for males in this age group in resting condition. HR decreased to 69.4 BPM after exposure to Sphere GS and further decreased to 66 BPM after exposure to Pyramid GS. Both considered Good HR conditions for males in this age group in resting condition. Average HR among female participants was 74 BPM in base condition which is considered average HR for females in this age group in resting condition. HR decreased to 67 BPM after exposure to Stereo and to 68 BPM after exposure to Sphere and Pyramid GS. All considered within the range of Great condition for females in this age group in resting condition.

Heart beat [BPM]	Base Condition	Sphere GS	Pyramid GS	Stereo (Control)
General	73	69	67	69
Male	72.7 (average)	69.4 (Good)	66 (Good)	70.1 (average)
Female	74 (average)	68 (Great)	68 (Great)	67 (Great)

Table 3: E1 Average heart rate among participants (N=19)

Blood Pressure:

Average Blood Pressure of participants decreased from 120/80 in base condition, which is considered Elevated Blood Pressure according to the American Heart Association, to 113/78 following Stereo, 112/76 following Sphere GS and 111/77 following Pyramid GS, all considered normal. Male participants show a decrease in both systolic and diastolic blood pressure following exposure to Sphere and Pyramid GS. Female participants show a decrease in both systolic and diastolic blood pressure following exposure to all sound stimuli with GS Sphere having the most significant results (Table 4)

Blood pressure	Base	Sphere GS	Pyramid GS	Stereo (Control)
General	120/80	112/76	111/77	113/78
Male	116/81	116/77	111/74	118/89
Female	113/78	105/74	108/80	106/75

Table 4: E1 Average Blood Pressure among participants (N=19)

Faraday Waves Pattern Distribution:

Cymascopic analysis of the wave files show a distinct correlation between the projected GS shape and its Faraday wave pattern. Importantly, all sound stimuli play the exact same sound sample - same frequency combination (272.2 Hz & 544.4 Hz) in the same loop, duration, and SPL and measured under identical conditions. Evidently, Pyramid GS creates a triangular pattern, Cube GS creates a square pattern and Sphere GS creates a circular pattern. Hence, identical sound frequency samples result in different Faraday wave patterns as a result of the sound spatial propagation (Figure 7A, 7B, 7C).

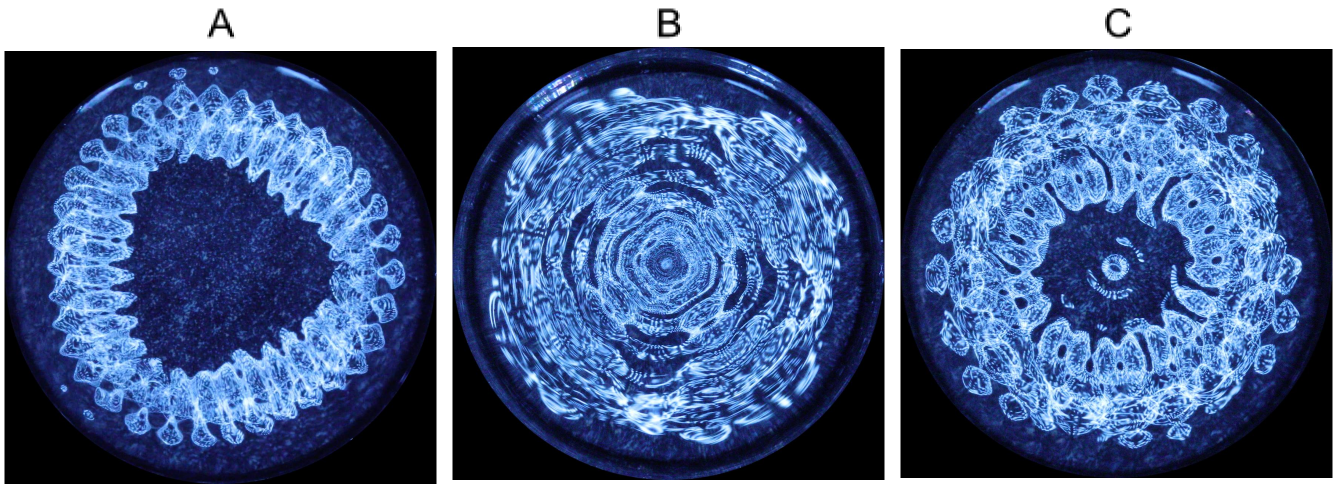


Figure 7: Faraday waves patterns morphology. Figure 7A: Faraday waves patterns following excitation by Pyramid Geometric Sound projection. Figure 7B: Faraday waves patterns following excitation by Cube Geometric Sound projection. Figure 7C: Faraday waves patterns following excitation by Sphere Geometric Sound projection

DISCUSSION:

This study investigated the effect of GS on brain wave activity, ANS markers and general well-being. In order to demonstrate the spatial differences of the different GS projections we further studied Faraday waves pattern distribution. Results show encouraging implications of immersion in GS projections on brain wave topologic power amplitude and connectivity patterns across three analysis paradigms. Results indicate GS is prone to induce relaxation, improve sense of well-being and stress related coping mechanisms according to behavioral and ANS measurements. GS is indicated to result in discrete effects on Faraday wave pattern distribution.

EEG results indicate a significant decrease in Alpha activity between Base condition (no sound) and all sound stimuli, with enhanced effect in all GS projections compared to control (stereo). Most significant results of Alpha decrease are obtained during exposure to Pyramid GS. Studies suggest that high resolution sound stimuli enhances relaxation compared to low resolution sound stimuli while showing decrease in Alpha activity [70]. Decrease in Alpha activity was also observed while monitoring relaxation effects of listening to monochord compared to progressive muscle relaxation tapes of the same length and sonic characteristics during chemotherapy [57-120]. Lower levels of Alpha activity in the left front central region, as demonstrated here, were significantly associated with higher levels of self acceptance, environmental mastery, personal growth and total psychological well-being [121], also suggesting a positive effect on cardiovascular and respiratory systems in accordance with mood induction [122]. Decrease in Alpha is reported to relate to higher levels of blood oxygenation [123].

Observation of EEG results in conjunction with participants' testimonials imply participants were in a state of enhanced concentration, i.e. immersion [124]. Magosso et al. reported that while being immersed in a Virtual Reality (VR) experience, Alpha is shown to decrease during arithmetic tasks compared to purely mental tasks, suggesting by the authors that attention is being imposed inwards [125]. The observed effect of GS may indicate that the brain derives spatial information of the geometric shapes and mathematical attributes of sound through hearing. Another non-traditional interpretation of these results could suggest the mathematical component of GS supports analytical and logical thinking, usually attributed to left hemisphere processing, while its sonic and melodic component supports holistic and creative thinking, usually attributed to right hemisphere processing. Thus suggesting GS could improve deep cohesion and communication of left and right hemispheres while strengthening a healthy sense of self awareness and mind-body connection. This indication is demonstrated by topological analysis showing symmetrical patterns in both hemispheres in all GS projections compared to control in the Alpha band. Analysis of EEG results in conjunction with participants' testimonials and behavioral effects suggests participants were in a state of relaxed alertness, also known as orchestrated immersion in which a focused attention is inhibited, which is considered the optimal condition for learning [126, 127].

The implications of these results could suggest non-invasive brain rehabilitation. For example, studies demonstrate that people with ADHD exhibit increased brain activity in frontal and temporal regions, mostly in the left hemisphere, in situations involving intellectual stress [128-129]. Major Depressive Disorder (MDD) is related to a decrease of Alpha symmetry [130-131]. We suggest GS effects on Alpha symmetry could support MDD rehabilitation and that specific GS projections could be used to relieve challenges and balance brain activity in left and right regions. Furthermore, this overall body of results suggests a brain rehabilitation practice that could possibly support neurotrauma rehabilitation.

Brain plasticity supports neurotrauma rehabilitation [55, 56][132], and is also used with Brain-Computer Interface (BCI) and neurofeedback processes to model and ignite non-functional areas; both methods require active participation [133]. Moreover, considering Hebbian Learning [134], it could be assumed that long term exposure to GS could possibly support cognitive recovery processes from neurotrauma while supporting rehabilitation of related mood disorders. The method at hand incorporates brain rehabilitation processes while being emotionally and physically beneficial as it incorporates benefits of sound / music therapies. Notably, GS proposes a method that does not require active participation and could support rehabilitation for unconscious conditions. These indications should be further investigated in future research.

Brain waves are known to entrain to a sound frequency, or combination of frequencies (interval) [50-52]. This study indicates brain waves are affected differently not only by sound frequency but also by the spatial properties of sound propagation. Results show different brain waves activity, connectivity and topological patterns during exposure to the different sound stimuli Pyramid, Cube, Sphere GS and control (Stereo) - all playing the same sound sample. The sound sample tested, an interval of an octave between 272.2 Hz and 544.4 Hz, showed significant changes in brain connectivity patterns mainly in the Alpha band. As power amplitude value is shown to decrease in the Alpha band during exposure to all sound stimuli but mostly in all GS projections, it can be concluded that connectivity patterns are of high significance. Furthermore, Topological analysis shows significant changes in the Alpha band during exposure to all sound stimuli, and in the Beta and Gamma bands only during exposure to GS. These results are inline with power amplitude analysis. Changes occur mostly in all GS shapes compared to control and mainly in Pyramid and Cube GS projections. Though results above 64 Hz were excluded from the analysis paradigm, possible effect in higher frequency ranges is plausible and should be further investigated in future analysis using different filters. Notably, at this point we can not conclude whether the effects in EEG are specific for spatiality of the sound projections, due to resulting spectral filtering or a combination of both factors. It is plausible that different intervals, frequencies and frequency ranges will produce alternate patterns across varied brain wave bands.

Although the effect of immersion in GS was largely compared by participants to meditation, brain activity patterns differ. Meditation and mindfulness are commonly related to enhanced activity in the Alpha and Theta bands, [130-131] which was not observed with exposure to GS. However, it has been found that different types of meditation as well as different types of neurofeedback result in a variance of brain activity patterns [132-133]. One possible explanation is that GS activates and affects the brain differently than methods related to silence, while achieving similar results related to enhanced relaxation, sense of focus, self awareness, positive emotional and physical function. We hypothesize that the positive effect of relaxation following regular meditation and mindfulness practice, also resulting in improved immune function [72], would remain with continued exposure to GS.

The emotional benefits of GS came forth in participants' testimonials and behavioral effects. Notably, both the MDMQ and custom questionnaires show similar patterns and a significant enhancement in reported sense of happiness, relaxed, deeply relaxed and confidence along with a significant decrease in reported sense of depression, fear, restlessness, nervousness, frustration, bad, worn out and uneasiness. Most significant items results are reported in enhanced sense of relaxation and decreased sense of nervousness and bad feelings. The positive trend towards improved well-being is maintained in items that did not generate significant statistical results. General testimonials from participants indicate improved sense of well-being including enhanced sense of focus, enhanced imagery including elaborated images, colors and memories, reports of a meditative feeling and improved self esteem. These results indicate sound medicine in general and GS in particular could be considered as a valid non-invasive method to relieve stress after a short exposure.

While it is difficult to differentiate the effect of GS from control by behavioral response, further information on the enhanced effect of GS can be gathered from ANS results. Measurements show significant improvement in participants' HR and Blood Pressure especially following exposure to GS compared to control. Among all participants Pyramid GS showed the highest effect and lowest rates of HR, while Blood Pressure reduced the most at Sphere GS. Male participants show a decrease in both systolic and diastolic blood pressure only following exposure to GS. Exposure to control (Stereo) showed an increase in both systolic and diastolic blood pressure among male participants. Female participants show a decrease in both systolic and diastolic blood pressure following exposure to all sound stimuli with Sphere GS having the most significant results. Male participants also present improved HR only following exposure to GS and not control. Results are inline with research showing reduced HR, reduced systolic and diastolic blood pressure along with improved pain endurance following exposure to music therapy [135] and may indicate GS could be used to improve pain endurance.

Faraday wave morphology pattern analysis indicates that each GS shape creates a mirroring pattern. This result is novel in the field of sound induced Faraday waves, suggesting patterns morphology is affected by the spatial properties of sound. This indication is in agreement with EEG and ANS patterns observed following excitation by GS. Notably, Kumeta et al. [136] demonstrated variation in effect on cells following audible sound excitation to be influenced by wave-form independently of frequency. Furthermore, the documented images indicate the sound is indeed projected in the said geometric shapes and stand as a testimonial for the holographic nature of sound (Figure 7A-, 7C). The holographic principle of sound hypothesis suggests that each sound "particle" holds all of its spectral information including its spatial information. Thus, even a mono or stereo recording of a 3D GS shape projection includes characteristics of its spatial propagation in space. This may imply a process of geometric synchronization which could possibly take place in other geometric substances such as molecules. Another possible application of this observation could suggest that polluted water with broken crystal structure could be cleaned and restored to its coherent geometric structure following excitation by GS. These are just a few possible applications of the possibilities emerging from this observation.

Immersion in GS greatly relies upon the use of a sound system that can enclose people within the projected GS shapes. Immersion creates an effect influential on the entire cavity, whether human or any other natural system. The used sound technology, both software and hardware, and high resolution sound projection it guarantees are responsible for the accuracy of the geometric and mathematical components of the sound projection as well as on sound's dynamics. High resolution sound stimuli was found to affect cells as a valuable nutrient at the G0 stage (Quiescence) [137] and enhance relaxation [70]. In biology, neuroscience and behavioral design it has been shown that structure and function are intimately related - shape informs function and function determines form [18, 135, 138-139]. It is probable that form represents function and could possibly affect it. In a fractal syntropic system such as nature, including human physiology and psychology, shape's function informs and inevitably constantly imposes its characteristics on its surroundings. It is a feedback loop between developmental stages governed and tightly related to mathematics and fundamental geometry.

Study limitations:

Participants were recruited through an open call and hold relatively homogeneous characteristics. EEG results were collected by two different teams positioned slightly differently in the space; However, participants were located in the same location in the space and of the sound projection. The stimuli was projected within <85db and was manually mixed to the same perceived loudness; measured levels of SPL were not collected. Notably, spatial sound projections are highly indicated to result in significant comparative differences between measured SPL, thus the audial perceived loudness of the projection does not necessarily correlate to its SPL. Faraday Waves data was documented once, further observations should be conducted to verify the presented results. The effect of the sound stimuli frequency should be further investigated - it is unclear if presented results are solely due to the projected GS, the excitation frequencies or their combination. These aspects should be further investigated to promote understanding of sound frequencies and spatial sound on human physiology and Faraday waves pattern morphology. Further, while this research tested three GS shapes (Pyramid, Cube, Sphere), further research should document the effect of more GS shapes and other mathematical sound attributes. Despite these limitations this is an important study demonstrating sound has distinct effects on biological mechanisms and the power to influence them. The effect shown on brain wave power amplitude, topology and connectivity patterns, ANS markers and Faraday waves pattern morphology suggest sound characteristics other than excitation frequency can result in varied response patterns.

CONCLUSION:

This study sought to combine spatial sound technology, geometry, mathematics and sound medicine to entrain natural systems into coherency. The overall body of results, replicated in two experiments in 2017 and 2018, indicate this relation is valid. GS was shown to affect Faraday Waves patterns morphology indicating sound's spatial properties affects its wave distribution. This observation suggests manipulation of matter through spatial properties of sound by means of geometric and mathematical entrainment. GS had a distinct effect on brain wave topology, power amplitude and connectivity patterns compared to control and base condition. Effect is mainly observed in the Alpha band, some effects are observed in the Beta and Gamma bands. GS effect on brain waves connectivity patterns indicates each GS projection, hence mathematical information, is generating a unique pattern. GS was shown to have an enhanced positive effect on blood pressure and HR compared to control. The effect was more present among male participants compared to female participants who showed improved measurements following exposure to all sound stimuli. Results are inline with behavioral reports of improved sense of relaxation, happiness, confidence, restlessness, fear, nervousness, uneasiness, worn out, depression and bad feelings following exposure to all sound stimuli. Accordingly, the absolute majority of participants reported the overall experience was positive, uplifting and beneficial. The difference in results between GS and control, as well as between the different GS shapes was maintained in brain wave topology power amplitude, connectivity patterns, HR and blood pressure. Thus further suggesting the body can perceive the difference between the geometries and their spatial characteristics through sound. Results indicate GS may be beneficial to treat people suffering from a line of stress related conditions as well as neurotrauma. We believe GS may offer a new methodology for a non-invasive medicinal practice as well as a new understanding of how mathematics governs growth and possibly support efficient reestablishment of natural systems following exposure to a stimuli of mathematical nature. Thus, exposure to geometry and mathematical ordering by a medium such as sound, may provide the means to affect natural systems and human biology as demonstrated in this study. Further studies on GS should shed more light on the underlying mechanism resulting in these effects

DATA AVAILABILITY:

The data used to support the findings of this study are included within the article. Additional data are available from the corresponding author upon request.

CONFLICT OF INTEREST:

The authors declare that they have no conflicts of interest.

FINANCIAL DISCLOSURE STATEMENT:

The authors received no specific funding for this work.

ACKNOWLEDGEMENTS:

Dr. Claire Glanois, Dr. Anat Barnea, Prof. Thomas Feiner, Frank Hagger, John Stuart Reid, Ilana Gelernter, Davide Sometti, Giulia Righetti, Naomi Geffen, Yehuda Naim, Elif Yildiz, Vladimir D. Razhev, Philipp Budras, Riki Elkayam, Yiwen Li Hegner, Amira Val Baker, Paul Oomen, 4DSOUND and the Spatial Sound Institute, MONOM team especially Silvia, Gratia and Mathis, all the participants in the experiments for their trust, time and honesty and the beloved Yonatan Naim who inspired this research from many light years away.

SUPPLEMENTARY MATERIALS AND SUPPORTING INFORMATION

S1 Appendix. Sound Samples Appendix 1

S2 Appendix. Custom Questionnaire Appendix 2
S3 Appendix. Connectivity Patterns Observed at Sporadic Frequencies Appendix 3
S4 Appendix. General Free Testimonials E1+E2 Appendix 4

REFERENCES:

1. The sound is the scenery [Internet]. rona-geffen. Available from: http://www.ronageffen.com/copy-of-the-sound-is-the-scenery
2. Oomen P, Holleman P, de Klerk L. 4DSOUND: A New Approach to Spatial Sound Reproduction & Synthesis. Living Architecture Systems Symposium White Papers. Toronto: Riverside Architectural Press. 2016; 238 - 245.
3. Reid JS. The special relationship between sound and light, with implications for sound and light therapy. Subtle Energies & Energy Medicine Journal Archives [Internet]. 2006;17(3). Available from: https://journals.sfu.ca/seemj/index.php/seemj/article/view/47
4. Cymascope.com. [Internet]. Available from: http://cymascope.com/cyma_research/oceanography.html
5. Yamagishi MEB, Shimabukuro AI. Nucleotide frequencies in human genome and fibonacci numbers. Bulletin Math Biology [Internet]. 2008;70(3):643–53. Available from: http://dx.doi.org/10.1007/s11538-007-9261-6
6. Hecht L. Mysterium Microcosmicum: The Geometric Basis for the Periodicity of the Elements. 21st Century Science & Technology. 1988; 1(2)
7. Torquato S, Zhang G, de Courcy-Ireland M. Uncovering multiscale order in the prime numbers via scattering. Journal of Statistical Mechanics [Internet]. 2018;2018(9):093401. Available from: http://dx.doi.org/10.1088/1742-5468/aad6be
8. Meijer DKF, Geesink JH. Phonon guided biology. Architecture of life and conscious perception are mediated by toroidal coupling of phonon, photon, and electron information fluxes at discrete eigenfrequencies. Neuroquantology [Internet]. 2016;14(4). Available from: http://dx.doi.org/10.14704/nq.2016.14.4.985
9. Tanemura M, Hiwatari Y, Matsuda H, Ogawa T, Ogita N, Ueda A. Geometrical Analysis of Crystallization of the Soft-Core Model, Progress of Theoretical Physics [Internet]. 1977; 58(4): 1079–1095, Available from: https://doi.org/10.1143/PTP.58.1079
10. Office Masaru Emoto [Internet]. Masaru-emoto.net. Available from: https://www.masaru-emoto.net/en
11. Vedaaustin.com. [Internet]. Available from: https://www.vedaaustin.com/
12. Sinha S. The Fibonacci Numbers and Its Amazing Applications, International Journal of Engineering Science Invention. 2017; 6(9): 7-14
13. Minarova N.The Fibonacci Sequence: Nature's Little Secret, CRIS Bulletin [Internet]. 2014; 2014(1):7-17. Available from: DOI: 10.2478/cris-2014-0001
14. Ricketts RM. The biologic significance of the divine proportion and Fibonacci series. American Journal of Orthodontics [Internet]. 1982;81(5):351–70. Available from: http://dx.doi.org/10.1016/0002-9416(82)90073-2

15. Grob V, Pfeifer E, Rutishauser R. Sympodial construction of Fibonacci-type leaf rosettes in Pinguicula moranensis (Lentibulariaceae). Annals of Botany [Internet]. 2007;100(4):857–63. Available from: http://dx.doi.org/10.1093/aob/mcm184
16. K. Rajput C. A classical geometric relationship that reveals the golden link in nature. J Adv Math [Internet]. 2019; 17:401–13. Available from: http://dx.doi.org/10.24297/jam.v17i0.8498
17. Coldea R, Tennant DA, Wheeler EM, Wawrzynska E, Prabhakaran D, Telling M, et al. Quantum criticality in an Ising chain: experimental evidence for emergent E8 symmetry. Science [Internet]. 2010;327(5962):177–80. Available from: http://dx.doi.org/10.1126/science.1180085
18. Purnell, M. C., Butawan, M. B. A., & Ramsey, R. D. Bio-field array: A dielectrophoretic electromagnetic toroidal excitation to restore and maintain the golden ratio in human erythrocytes. Physiological Reports, 2018;6(11). https://doi.org/10.14814/phy2.13722
19. Zia-ur-Rehman, Shah A, Muhammad N, Ali S, Qureshi R, Butler IS. Synthesis, characterization and DNA binding studies of penta- and hexa-coordinated diorganotin(IV) 4-(4-nitrophenyl)piperazine-1-carbodithioates. Journal of Organometallic Chemistry [Internet]. 2009;694(13):1998–2004. Available from: http://dx.doi.org/10.1016/j.jorganchem.2009.01.047
20. Sponer J, Leszczynski J, Hobza P. Electronic properties, hydrogen bonding, stacking, and cation binding of DNA and RNA bases. Biopolymers [Internet]. 2001;61(1):3–31. Available from: http://dx.doi.org/10.1002/1097-0282(2001)61:1<3::AID-BIP10048>3.0.CO;2-4
21. Koumoundouros T. Invisible dance of earth and Venus forms a stunning pentagrammic pattern in space [Internet]. ScienceAlert. 2019. Available from: https://www.sciencealert.com/the-celestial-dance-between-earth-and-venus-draws-a-stunning-pattern-through-space
22. Gordin MD. Paper tools and periodic tables: Newlands and Mendeleev draw grids. Ambix [Internet]. 2018;65(1):30–51. Available from: http://dx.doi.org/10.1080/00026980.2017.1418251
23. Akhtaruzzaman MD, Shafie AA. Geometrical Substantiation of Phi, the Golden Ratio and the Baroque of Nature, Architecture, Design and Engineering, International Journal of Arts [Internet]. 2011; 1(1): 1-22. Available from: doi:10.5923/j.arts.20110101.01
24. Sandborn MD, Sandborn MT, inventors. System and method for relating electromagnetic waves to sound waves. United States patent US6930235B2. 2005 Aug 16.
25. Atasoy S, Donnelly I, Pearson J. Human brain networks function in connectome-specific harmonic waves. Nature Communications [Internet]. 2016;7(1):10340. Available from: http://dx.doi.org/10.1038/ncomms10340
26. Rossing TD. Chladni's law for vibrating plates. American Journal of Physics [Internet]. 1982;50(3):271–4. Available from: http://dx.doi.org/10.1119/1.12866
27. Jenny H. Wave phenomena, vibrational effects and harmonic oscillations with their structure, kinetics, and dynamics. In: CYMATICS A Study of Wave Phenomena and Vibration. NH: Newmarket; 1974. p. 129–279.
28. Jin Oh Y. Experimental Study of Cymatics. IACSIT International Journal of Engineering and Technology. 2012;4(4):434–6. Available from: http://dx.doi.org/10.7763/ijet.2012.v4.404
29. Reid JS. Rediscovering the art and science of Sound healing. 2007 [Internet]. Available from: https://www.semanticscholar.org/paper/39347e66100adb6d613febd094dd217e78c5a111
30. Sheldrake M, Sheldrake R. Determinants of Faraday Wave-Patterns in Water Samples Oscillated Vertically at a Range of Frequencies from 50-200 Hz, WATER Journal [Internet]. 2017;9:1-27. Available From: DOI:10.14294/WATER.2017.6

31. Reid JS, Jun Park B, Ji S. Imaging Cancer and Healthy Cell Sounds in Water by Cymascope, Followed by Quantitative Analysis by Planck-Shannon Classifier, WATER Journal. 2019; 11: 43-54. Available from: DOI:10.14294/WATER.2019.6
32. McCaffrey R. Music listening: its effects in creating a healing environment. Journal of Psychosocial Nursing and Mental Health Services [Internet]. 2008;46(10):39–44. Available from: http://dx.doi.org/10.3928/02793695-20081001-08
33. Shin HS, Kim JH. Music therapy on anxiety, stress and maternal-fetal attachment in pregnant women during transvaginal ultrasound. Asian Nursing Research (Korean Soc Nurs Sci) [Internet]. 2011;5(1):19–27. Available from: http://dx.doi.org/10.1016/S1976-1317(11)60010-8
34. Harada T, Ishizaki, Ito, Aoi, "Study of Objective Evaluation of Effect of Psychological Relaxation Using Classic Music", International Medical Journal [Internet]. 2017; 24(1): 31 – 33
35. Leubner D, Hinterberger T. Reviewing the effectiveness of music interventions in treating depression. Front Psychol [Internet]. 2017; 8:1109. Available from: http://dx.doi.org/10.3389/fpsyg.2017.01109
36. Wells A, Hakanen EA. The emotional use of popular music by adolescents. Journalism Quarterly [Internet]. 1991;68(3):445–54. Available from: http://dx.doi.org/10.1177/107769909106800315
37. Schäfer T, Sedlmeier P, Städtler C, Huron D. The psychological functions of music listening. Front Psychol [Internet]. 2013; 4:511. Available from: http://dx.doi.org/10.3389/fpsyg.2013.00511
38. Gutgsell KJ, Schluchter M, Margevicius S, DeGolia PA, McLaughlin B, Harris M, et al. Music therapy reduces pain in palliative care patients: a randomized controlled trial. Journal of Pain and Symptom Management [Internet]. 2013;45(5):822–31. Available from: http://dx.doi.org/10.1016/j.jpainsymman.2012.05.008
39. Lee JH. The effects of music on pain: A meta-analysis. J Music Therapy [Internet]. 2016;53(4):430–77. Available from: http://dx.doi.org/10.1093/jmt/thw012
40. Abbey E, Reid JS, Ji S. Can music influence the longevity of human blood cells? Experiment [Internet]. 2017. Available from: DOI: 10.18258/9877
41. Kirste I, Nicola Z, Kronenberg G, Walker TL, Liu RC, Kempermann G. Is silence golden? Effects of auditory stimuli and their absence on adult hippocampal neurogenesis. Brain Struct Funct [Internet]. 2015;220(2):1221–8. Available from: http://dx.doi.org/10.1007/s00429-013-0679-3
42. Bailey M. Music therapists, once marginalized, come into the mainstream at children's hospitals. STAT [Internet]. 2016 Jun 27; Available from: https://www.statnews.com/2016/06/27/music-therapy-children-hospitals/
43. Foster B, Pearson S, Berends A, Mackinnon C. The Expanding Scope, Inclusivity, and Integration of Music in Healthcare: Recent Developments, Research Illustration, and Future Direction. Healthcare. 2021; 9(1):99. https://doi.org/10.3390/healthcare9010099
44. Carr, C., & Wigram, T.. Music therapy with children and adolescents in mainstream schools: A systematic review. *British Journal of Music Therapy*, 2009;*23*(1):3–18. https://doi.org/10.1177/135945750902300102
45. What is music therapy and how is it used in a hospital? [Internet]. Arnoldpalmerhospital.com. Available from: https://www.arnoldpalmerhospital.com/content-hub/what-is-music-therapy-and-how-is-it-used-in-a-hospital

46. Swanson AL. Music therapy in schools: Stimulating the mind and body to create positive change. In: Promoting mind–body health in schools: Interventions for mental health professionals. Washington: American Psychological Association; 2020. p. 233–44.
47. Nunner M. Sound Therapy and well-being: some scientific studies [Internet]. MedicinaNarrativa.eu. Fondazione ISTUD; 2017. Available from: https://www.medicinanarrativa.eu/sound-therapy-and-well-being-some-scientific-studie
48. Ferguson J. A brief history of sound therapy [Internet]. Sivana East. 2016. Available from: https://blog.sivanaspirit.com/brief-history-sound-therapy/
49. Uvnas-Moberg K, Petersson M. Oxytocin, a mediator of anti-stress, well-being, social interaction, growth and healing. Z Psychosom Med Psychother [Internet]. 2005;51(1):57–80. Available from: http://dx.doi.org/10.13109/zptm.2005.51.1.57
50. Oster G. Auditory beats in the brain. Scientific American [Internet]. 1973;229(4):94–102. Available from: http://dx.doi.org/10.1038/scientificamerican1073-94
51. Lane JD, Kasian SJ, Owens JE, Marsh GR. Binaural auditory beats affect vigilance performance and mood. Physiol Behav [Internet]. 1998;63(2):249–52. Available from: http://dx.doi.org/10.1016/s0031-9384(97)00436-8
52. Kasprzak C. Influence of Binaural Beats on EEG Signal. Acta Physica Polonica A 119 [Internet]. 2011; 119 (2011): 986-990. Available from: DOI:10.12693/APHYSPOLA.119.986
53. Jingjing Z. Effects of auditory training on cognitive function in patients with stroke – tomatis® research & publications [Internet]. Tomatisassociation.org. Available from: https://tomatisassociation.org/effects-of-auditory-training-on-cognitive-function-in-patients-with-stroke/
54. Frank E, Swartz HA, Kupfer DJ. Interpersonal and social rhythm therapy: managing the chaos of bipolar disorder. Biol Psychiatry [Internet]. 2000;48(6):593–604. Available from: http://dx.doi.org/10.1016/s0006-3223(00)00969-0
55. Martínez-Molina N, Siponkoski S-T, Kuusela L, Laitinen S, Holma M, Ahlfors M, et al. Resting-state network plasticity induced by music therapy after traumatic brain injury. Neural Plasticity [Internet]. 2021; 2021:1–18. Available from: http://dx.doi.org/10.1155/2021/6682471
56. Hegde S. Music-based cognitive remediation therapy for patients with traumatic brain injury. Front Neurol [Internet]. 2014; 5:34. Available from: http://dx.doi.org/10.3389/fneur.2014.00034
57. Lee E-J, Bhattacharya J, Sohn C, Verres R. Monochord sounds and progressive muscle relaxation reduce anxiety and improve relaxation during chemotherapy: a pilot EEG study. Complement Ther Med [Internet]. 2012;20(6):409–16. Available from: http://dx.doi.org/10.1016/j.ctim.2012.07.002
58. Dal Lin C, Radu CM, Vitiello G, Romano P, Polcari A, Iliceto S, et al. Sounds stimulation on in vitro HL1 cells: A pilot study and a theoretical physical model. Int J Mol Sci [Internet]. 2020;22(1):156. Available from: http://dx.doi.org/10.3390/ijms22010156
59. Pelling AE, Wilkinson PR, Stringer R, Gimzewski JK. Dynamic mechanical oscillations during metamorphosis of the monarch butterfly. J R Soc Interface [Internet]. 2009;6(30):29–37. Available from: http://dx.doi.org/10.1098/rsif.2008.0224
60. Jung J, Kim S-K, Kim JY, Jeong M-J, Ryu C-M. Beyond chemical triggers: Evidence for sound-evoked physiological reactions in plants. Front Plant Sci [Internet]. 2018; 9:25. Available from: http://dx.doi.org/10.3389/fpls.2018.00025

61. Hassanien RHE, Hou T-Z, Li Y-F, Li B-M. Advances in effects of sound waves on plants. J Integr Agric [Internet]. 2014;13(2):335–48. Available from: http://dx.doi.org/10.1016/s2095-3119(13)60492-x
62. Gordon TAC, Radford AN, Davidson IK, Barnes K, McCloskey K, Nedelec SL, et al. Acoustic enrichment can enhance fish community development on degraded coral reef habitat. Nat Commun [Internet]. 2019;10(1):5414. Available from: http://dx.doi.org/10.1038/s41467-019-13186-2
63. Talks T. TEDxLAMiracleMile - Jim Gimzewksi - 01/23/10 [Internet]. Youtube; 2010. Available from: https://www.youtube.com/watch?v=DpUkKYmuCI8&t=0s&ab_channel=TEDxTalks
64. Sarris J, Kavanagh DJ, Byrne G, Bone KM, Adams J, Deed G. The Kava Anxiety Depression Spectrum Study (KADSS): a randomized, placebo-controlled crossover trial using an aqueous extract of Piper methysticum. Psychopharmacology (Berl) [Internet]. 2009;205(3):399–407. Available from: http://dx.doi.org/10.1007/s00213-009-1549-9
65. Cui Y-H, Zheng Y. A meta-analysis on the efficacy and safety of St John's wort extract in depression therapy in comparison with selective serotonin reuptake inhibitors in adults. Neuropsychiatr Dis Treat [Internet]. 2016; 12:1715–23. Available from: http://dx.doi.org/10.2147/NDT.S106752
66. Tarleton EK, Littenberg B, MacLean CD, Kennedy AG, Daley C. Role of magnesium supplementation in the treatment of depression: A randomized clinical trial. PLoS One [Internet]. 2017;12(6):e0180067. Available from: http://dx.doi.org/10.1371/journal.pone.0180067
67. Enriquez-Geppert S, Smit D, Pimenta MG, Arns M. Neurofeedback as a treatment intervention in ADHD: Current evidence and practice. Curr Psychiatry Rep [Internet]. 2019;21(6):46. Available from: http://dx.doi.org/10.1007/s11920-019-1021-4
68. Goldsby TL, Goldsby ME, McWalters M, Mills PJ. Effects of singing bowl sound meditation on mood, tension, and well-being: An observational study. J Evid Based Complementary Altern Med [Internet]. 2017;22(3):401–6. Available from: http://dx.doi.org/10.1177/2156587216668109
69. Sound affects: Sound therapy, altered states of consciousness and improved health and wellbeing by lyz Cooper MA, MSc, FICNM [Internet]. Britishacademyofsoundtherapy.com. Available from: https://www.britishacademyofsoundtherapy.com/wp-content/uploads/2016/01/ASC-research-article-HealthySound.pdf
70. Ito S, Harada T, Miyaguchi M, Ishizaki F, Chikamura C, Kodama Y. Effect of High-Resolution Audio Music Box Sound on EEG. International Medical Journal. 2016; 23(1): 1 – 3.
71. Merkes M. Mindfulness-based stress reduction for people with chronic diseases. Aust J Prim Health [Internet]. 2010;16(3):200–10. Available from: http://dx.doi.org/10.1071/PY09063
72. Davidson RJ, Kabat-Zinn J, Schumacher J, Rosenkranz M, Muller D, Santorelli SF, et al. Alterations in brain and immune function produced by mindfulness meditation. Psychosom Med [Internet]. 2003;65(4):564–70. Available from: http://dx.doi.org/10.1097/01.psy.0000077505.67574.e3

73. Shin HS, Kim JH. Music therapy on anxiety, stress, and maternal-fetal attachment in pregnant women during transvaginal ultrasound. Asian Nurs Res (Korean Soc Nurs Sci) [Internet]. 2011;5(1):19–27. Available from: http://dx.doi.org/10.1016/S1976-1317(11)60010-8
74. Ramirez R, Planas J, Escude N, Mercade J, Farriols C. EEG-based analysis of the emotional effect of music therapy on palliative care cancer patients. Front Psychol [Internet]. 2018;9. Available from: http://dx.doi.org/10.3389/fpsyg.2018.00254
75. Kučikienė D, Praninskienė R. The impact of music on the bioelectrical oscillations of the brain. Acta Med Litu [Internet]. 2018;25(2):101–6. Available from: http://dx.doi.org/10.6001/actamedica.v25i2.3763
76. Banquet JP. Spectral analysis of the EEG in meditation. Electroencephalogr Clin Neurophysiol [Internet]. 1973;35(2):143–51. Available from: http://dx.doi.org/10.1016/0013-4694(73)90170-3
77. Lutz J, Herwig U, Opialla S, Hittmeyer A, Jäncke L, Rufer M, et al. Mindfulness and emotion regulation--an fMRI study. Soc Cogn Affect Neurosci [Internet]. 2014;9(6):776–85. Available from: http://dx.doi.org/10.1093/scan/nst043
78. Creswell JD, Way BM, Eisenberger NI, Lieberman MD. Neural correlates of dispositional mindfulness during affect labeling. Psychosom Med [Internet]. 2007;69(6):560–5. Available from: http://dx.doi.org/10.1097/psy.0b013e3180f6171f
79. Shahinfard E, Robin Hsiung G-Y, Boyd L, Jacova C, Slack P, Kirkland K. P4‐042: An FMRI study to investigate the benefits of music therapy in patients with Alzheimer's disease. Alzheimers Dement [Internet]. 2016;12(7S_Part_21):1030–1. Available from: http://dx.doi.org/10.1016/j.jalz.2016.06.2131
80. Raglio A, Galandra C, Sibilla L, Esposito F, Gaeta F, Di Salle F, et al. Effects of active music therapy on the normal brain: fMRI based evidence. Brain Imaging Behav [Internet]. 2016;10(1):182–6. Available from: http://dx.doi.org/10.1007/s11682-015-9380-x
81. Chuang C-Y, Han W-R, Li P-C, Song M-Y, Young S-T. Effect of long-term music therapy intervention on autonomic function in anthracycline-treated breast cancer patients. Integr Cancer Ther [Internet]. 2011;10(4):312–6. Available from: http://dx.doi.org/10.1177/1534735411400311
82. Shearer A, Hunt M, Chowdhury M, Nicol L. Effects of a brief mindfulness meditation intervention on student stress and heart rate variability. Int J Stress Manag [Internet]. 2016;23(2):232–54. Available from: http://dx.doi.org/10.1037/a0039814
83. Maydych V. The interplay between stress, inflammation, and emotional attention: Relevance for depression. Front Neurosci [Internet]. 2019; 13:384. Available from: http://dx.doi.org/10.3389/fnins.2019.00384
84. Liu Y-Z, Wang Y-X, Jiang C-L. Inflammation: The common pathway of stress-related diseases. Front Hum Neurosci [Internet]. 2017; 11:316. Available from: http://dx.doi.org/10.3389/fnhum.2017.00316
85. Rohleder N. Stimulation of systemic low-grade inflammation by psychosocial stress. Psychosom Med [Internet]. 2014;76(3):181–9. Available from: http://dx.doi.org/10.1097/PSY.0000000000000049
86. Calcia MA, Bonsall DR, Bloomfield PS, Selvaraj S, Barichello T, Howes OD. Stress and neuroinflammation: a systematic review of the effects of stress on microglia and the implications for mental illness. Psychopharmacology (Berl) [Internet]. 2016;233(9):1637–50. Available from: http://dx.doi.org/10.1007/s00213-016-4218-9

87. Ahmad AH, Zakaria R. Pain in Times of Stress. Malaysian J Med Sci [Internet]. 2015;22(Spec Issue):52-61. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4795524/
88. Geva N, Defrin R. Opposite effects of stress on pain modulation depend on the magnitude of individual stress response. J Pain [Internet]. 2018;19(4):360–371. Available from: http://dx.doi.org/10.1016/j.jpain.2017.11.011
89. Abdallah CG, Geha P. Chronic pain and chronic stress: Two sides of the same coin? Chronic Stress (Thousand Oaks) [Internet]. 2017; 1:247054701770476. Available from: http://dx.doi.org/10.1177/2470547017704763
90. Kimyai-Asadi A, Usman A. The role of psychological stress in skin disease. J Cutan Med Surg [Internet]. 2001;5(2):140–5. Available from: http://dx.doi.org/10.1007/bf02737869
91. Nakamura K, Sheps S, Arck PC. Stress and reproductive failure: past notions, present insights, and future directions. J Assist Reprod Genet [Internet]. 2008;25(2–3):47–62. Available from: http://dx.doi.org/10.1007/s10815-008-9206-5
92. Rooney KL, Domar AD. The relationship between stress and infertility. Dialogues Clin Neurosci [Internet]. 2018;20(1):41–7. Available from: http://dx.doi.org/10.31887/dcns.2018.20.1/klrooney
93. Bryan-Thomas J, Bicknell D, Brown D, Dennis S, Francis M, Robinson J. Relationship of Stress to Male Impotence. International Journal of Scientific and Research Publications. 2018; 8(2): 503-507. ISSN: 2250-3153. Available from: http://www.ijsrp.org/research-paper-0218.php?rp=P747231
94. Dimsdale JE. Psychological stress and cardiovascular disease. J Am Coll Cardiol [Internet]. 2008;51(13):1237–46. Available from: http://dx.doi.org/10.1016/j.jacc.2007.12.024
95. Song H, Fang F, Arnberg FK, Mataix-Cols D, Fernández de la Cruz L, Almqvist C, et al. Stress related disorders and risk of cardiovascular disease: population based, sibling controlled cohort study. BMJ [Internet]. 2019;365: l1255. Available from: http://dx.doi.org/10.1136/bmj.l1255
96. Lehrer P. Anger, stress, dysregulation produces wear and tear on the lung. Thorax [Internet]. 2006;61(10):833–4. Available from: http://dx.doi.org/10.1136/thx.2006.057182
97. Cohen S, Hamrick N, Rodriguez MS, Feldman PJ, Rabin BS, Manuck SB. Reactivity and vulnerability to stress-associated risk for upper respiratory illness. Psychosom Med [Internet]. 2002;64(2):302–10. Available from: http://dx.doi.org/10.1097/00006842-200203000-00014
98. Lehrer P, Feldman J, Giardino N, Song H-S, Schmaling K. Psychological aspects of asthma. J Consult Clin Psychol [Internet]. 2002;70(3):691–711. Available from: http://dx.doi.org/10.1037/0022-006x.70.3.691
99. Sabharwal R. The link between stress disorders and autonomic dysfunction in muscular dystrophy. Front Physiol [Internet]. 2014; 5:25. Available from: http://dx.doi.org/10.3389/fphys.2014.00025
100. Razzoli M, Lindsay A, Law ML, Chamberlain CM, Southern WM, Berg M, et al. Social stress is lethal in the mdx model of Duchenne muscular dystrophy. EBioMedicine [Internet]. 2020;55(102700):102700. Available from: http://dx.doi.org/10.1016/j.ebiom.2020.102700
101. Wippert P-M, Rector M, Kuhn G, Wuertz-Kozak K. Stress and alterations in bones: An interdisciplinary perspective. Front Endocrinol [Internet]. 2017; 8:96. Available from: http://dx.doi.org/10.3389/fendo.2017.00096

102. Segerstrom SC, Miller GE. Psychological stress and the human immune system: a meta-analytic study of 30 years of inquiry. Psychol Bull [Internet]. 2004;130(4):601–30. Available from: http://dx.doi.org/10.1037/0033-2909.130.4.601
103. Schneiderman N, Ironson G, Siegel SD. Stress and health: psychological, behavioral, and biological determinants. Annu Rev Clin Psychol [Internet]. 2005;1(1):607–28. Available from: http://dx.doi.org/10.1146/annurev.clinpsy.1.102803.144141
104. Toussaint L, Shields GS, Dorn G, Slavich GM. Effects of lifetime stress exposure on mental and physical health in young adulthood: How stress degrades and forgiveness protects health. J Health Psychol [Internet]. 2016;21(6):1004–14. Available from: http://dx.doi.org/10.1177/1359105314544132
105. Zhang Y-B, Zhong Z-M, Hou G, Jiang H, Chen J-T. Involvement of oxidative stress in age-related bone loss. J Surg Res [Internet]. 2011;169(1): e37-42. Available from: http://dx.doi.org/10.1016/j.jss.2011.02.033
106. Lavretsky H, Newhouse PA. Stress, inflammation, and aging. Am J Geriatr Psychiatry [Internet]. 2012;20(9):729–33. Available from: http://dx.doi.org/10.1097/JGP.0b013e31826573cf
107. Trüeb RM. Oxidative stress in ageing of hair. Int J Trichology [Internet]. 2009;1(1):6–14. Available from: http://dx.doi.org/10.4103/0974-7753.51923
108. Amen DG. Change Your Brain, Change Your Life. Harmony Books; 2015. p. 8–33.
109. Hegde S. Music and Neural Plasticity [Video]. India Alliance 9th Annual Fellows' Meeting. 2019. Available from: https://youtu.be/e8YPJj0Sq9M (Accessed: April 20, 2023).
110. Magee WL, Clark I, Tamplin J, Bradt J. Music interventions for acquired brain injury (Review), Cochrane Database of Systematic Reviews [Internet]. 2017;1(1). Available from: DOI: 10.1002/14651858.CD006787.pub3.)
111. Vik BMD, Skeie GO, Specht K. Neuroplastic Effects in Patients With Traumatic Brain Injury After Music-Supported Therapy. Front Hum Neurosci. 2019;13(177). Available from: DOI:10.3389/fnhum.2019.00177)
112. Guétin S, Soua B, Voiriot G, Picot MC, Hérisson C. The effect of music therapy on mood and anxiety-depression: an observational study in institutionalised patients with traumatic brain injury. Ann Phys Rehabil Med [Internet]. 2009;52(1):30-40. Available from: DOI:10.1016/j.annrmp.2008.08.009
113. Reddy BU, Phanisree P, Priyanka M, Kavitha D, Indira S, Bhandarkar P, et al. Effect of music therapy in patients with moderate-to-severe traumatic brain injury. J Datta Meghe Inst Med Sci Univ [Internet]. 2017;12:51-4. Available from: DOI:12.51.10.4103/jdmimsu.jdmimsu_23_17.)
114. Bigler ED. The lesion(s) in traumatic brain injury: implications for clinical neuropsychology, Archives of Clinical Neuropsychology [Internet]. 2001;16(2):95-131. ISSN 0887-6177, Available from: DOI:10.1016/S0887-6177(00)00095-0)
115. Acutonics® institute of integrative medicine [Internet]. Acutonics.com. Available from: https://acutonics.com/
116. Zalesky A, Fornito A, Bullmore ET. Network-based statistic: identifying differences in brain networks. Neuroimage [Internet]. 2010;53(4):1197–207. Available from: http://dx.doi.org/10.1016/j.neuroimage.2010.06.041
117. Oostenveld R, Fries P, Maris E, Schoffelen J-M. FieldTrip: Open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. Comput Intell Neurosci [Internet]. 2011; 2011:156869. Available from: http://dx.doi.org/10.1155/2011/156869

118. Nolte G, Bai O, Wheaton L, Mari Z, Vorbach S, Hallett M. Identifying true brain interaction from EEG data using the imaginary part of coherency. Clin Neurophysiol [Internet]. 2004;115(10):2292–307. Available from: http://dx.doi.org/10.1016/j.clinph.2004.04.029
119. Brain Connectivity Toolbox [Internet]. Google.com. Available from: https://sites.google.com/site/bctnet/home?authuser=0
120. Bhattacharya J, Lee E-J. Modulation of EEG theta band signal complexity by music therapy. Int J Bifurcat Chaos [Internet]. 2016;26(01):1650001. Available from: http://dx.doi.org/10.1142/s0218127416500012
121. Urry HL, Nitschke JB, Dolski I, Jackson DC, Dalton KM, Mueller CJ, et al. Making a life worth living: neural correlates of well-being: Neural correlates of well-being. Psychol Sci [Internet]. 2004;15(6):367–72. Available from: http://dx.doi.org/10.1111/j.0956-7976.2004.00686.x
122. Huotilainen M, Ahonen L, Gröhn M. Effects of pleasant and unpleasant auditory mood induction on the performance and in brain activity in cognitive tasks. Proceedings of the 18th International Conference on Auditory Display; 2012 July 18-21; Helsinki, Finland: Finnish Institute of Occupational Health; 2012. p. 242–3.
123. Yuan H, Liu T, Szarkowski R, Rios C, Ashe J, He B. Negative covariation between task-related responses in alpha/beta-band activity and BOLD in human sensorimotor cortex: an EEG and fMRI study of motor imagery and movements. Neuroimage [Internet]. 2010;49(3):2596–606. Available from: http://dx.doi.org/10.1016/j.neuroimage.2009.10.028
124. Lim S, Yeo M, Yoon G. Comparison between concentration and immersion based on EEG analysis. Sensors (Basel) [Internet]. 2019;19(7):1669. Available from: http://dx.doi.org/10.3390/s19071669
125. Magosso E, De Crescenzio F, Ricci G, Piastra S, Ursino M. EEG alpha power is modulated by attentional changes during cognitive tasks and Virtual Reality immersion. Comput Intell Neurosci [Internet]. 2019; 2019:7051079. Available from: http://dx.doi.org/10.1155/2019/7051079
126. Caine RN, Caine G, McClintic C, Klimek KJ. 12 brain/mind learning principles in action. Thousand Oaks, CA: Corwin Press; 2016. Available from: https://dx.doi.org/10.4135/9781483394275
127. Ramakrishnan J. Brain Based Learning Strategies. IJIRS. 2018; 2(5): 236-342
128. Amen DG, Carmichael BD. High-resolution brain SPECT imaging in ADHD. Annals of Clinical Psychiatry. 1997 Jun;9(2):81-6. Available from: DOI: 10.1023/a:1026201218296
129. Kaur C, Singh P. EEG derived neuronal dynamics during meditation: Progress and challenges. Advances in Preventive Medicine [Internet]. 2015; 2015:614723. Available from: http://dx.doi.org/10.1155/2015/614723
130. Nyström C, Matousek M, Hällström T. Relationships between EEG and clinical characteristics in major depressive disorder. Acta Psychiatr Scand [Internet]. 1986;73(4):390–4. Available from: http://dx.doi.org/10.1111/j.1600-0447.1986.tb02700.x
131. Fingelkurts AA, Fingelkurts AA, Rytsälä H, Suominen K, Isometsä E, Kähkönen S. Impaired functional connectivity at EEG alpha and theta frequency bands in major depression. Hum Brain Mapp [Internet]. 2007;28(3):247–61. Available from: http://dx.doi.org/10.1002/hbm.20275
132. Walton AG. Different types of meditation change different areas of the brain, study finds [Internet]. Forbes. 2017. Available from: https://www.forbes.com/sites/alicegwalton/2017/10/05/different-types-of-meditation-change-the-brain-in-different-ways-study-finds/?sh=13040221f1ea

133. Lebowitz MS, Dams-O'Connor K, Cantor JB. Feasibility of computerized brain plasticity-based cognitive training after traumatic brain injury. J Rehabil Res Dev [Internet]. 2012;49(10):1547–56. Available from: http://dx.doi.org/10.1682/jrrd.2011.07.0133
134. Keysers C, Gazzola V. Hebbian learning and predictive mirror neurons for actions, sensations and emotions. Philos Trans Royal Soc Lond B Biol Sci [Internet]. 2014;369(1644):20130175. Available from: http://dx.doi.org/10.1098/rstb.2013.0175
135. Nanda U, Pati D, Ghamari H, Bajema R. Lessons from neuroscience: form follows function, emotions follow form. Intelligent Buildings International [Internet]. 2013;5(sup1):61–78. Available from: http://dx.doi.org/10.1080/17508975.2013.807767
136. Kumeta M, Takahashi D, Takeyasu K, Yoshimura SH (2018) Cell type-specific suppression of mechanosensitive genes by audible sound stimulation. Plos One [Internet]. 2018; 13(1): 1-14. Available from: https://doi.org/10.1371/journal.pone.0188764
137. Reid JS. Rediscovering the art and science of Sound healing. 2007. Available from: https://www.semanticscholar.org/paper/39347e66100adb6d613febd094dd217e78c5a111
138. Banavar JR, Cooke TJ, Rinaldo A, Maritan A. Form, function, and evolution of living organisms. Proc Natl Acad Sci U S A [Internet]. 2014;111(9):3332–7. Available from: http://dx.doi.org/10.1073/pnas.1401336111
139. Hwang K. Form follows function, function follows form. J Craniofac Surg [Internet]. 2020;31(2):335. Available from: http://dx.doi.org/10.1097/SCS.0000000000005891