Archaeoacoustic Investigation of a Prehistoric Cave Site: Frequency-Dependent Sound Amplification and Potential Relevance for Neurotheology

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ABSTRACT

An archaeoacoustic study was recently conducted within the prehistoric cave system of *El Castillo* in northern *Spain*. With findings dating back at least 40800 years, archaeological studies of this cave have revealed the presence of prehistoric ritual activity associated with early shamanism. Simulated audio tones of varying frequencies were created and emitted from the location at which it is thought the shamans would conduct rituals within El Castillo, while the sound was simultaneously recorded from the likely location of potential observers or participants. Subsequent analysis identified a frequency-dependent amplification of recorded sound intensity for frequencies approaching the range of 100 Hz, with the greatest effect observed for 108 and 110 Hz. These results are markedly consistent with previous research of important or sacred sites which have shown significant sonic resonance features within this precise range of frequencies. Additional consideration is applied to the potential effects of 110 Hz physical stimuli on biological systems in the context of neurotheology and the associated biophysical analyses in order to demonstrate the potential importance of 110 Hz signals on religious experience and subjective states of consciousness.

Key Words: archaeoacoustics, frequency-dependence, consciousness, environmental psychology, neurotheology

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Introduction

The study of "*sacred sites*" has been relatively consistent throughout the social sciences and humanities, drawing careful attention to important historic, and often prehistoric, geographical locations which have contributed to our overall understanding of cultural development, particularly in the context of spiritual belief structure (Mazmudar & Mazmudar, 2004). However, more recent

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convergence with the physical sciences and a neurotheological understanding of religious experience has suggested that there may be some fundamental physical properties consistent across apparently sacred locations which could be related to the neurobiological bases of spirituality (Hill & Saroka, 2010). Caves in particular have been examined as important sites for ritual activity (Faulkner *et al.,* 1984; McNatt, 1996), especially in the context of practices associated with shamanism (Whitley, 1992). By combining this area of study with an approach consistent with environmental psychology and neurotheology, greater insight may be revealed regarding the biophysical relationships which may have affected the long-term use of specific sites as sacred ritual locations.

Archaeoacoustics, an interesting new method involved in the analysis of ancient sites, has been employed to reveal varied sound properties, many of which operate on the human physiological and emotional sphere. The documented effects of these acoustic properties on human cognitive processes (Cook *et al.,* 2008; Hill & Saroka, 2010) suggest that the inhabitants of these sites could have had knowledge of this process and probably used it to enhance their rituals (Debertolis, 2013). Simply stated, resonance is the phenomenon in which an object absorbs more energy at specific frequencies and emits the energy with greater intensity. This resonance of acoustic stimuli could then affect, for example, a human brain (Metzner, 1987). What was the impact of prehistoric peoples' use of sound on human perception? It is quite possible that ancient humans moving inside a cave could have noticed how different sounds produced an influence over subjective perceptions depending on the place and position inside of the cave, thus facilitating different states of consciousness without the use of drugs or other chemical substances.

The cave of El Castillo is part of a larger archaeological complex within the mountain of Monte Castillo, known as the Caves of Monte Castillo. The location of this cave complex bears a number of interesting, albeit potentially circumstantial, connections with the burial rites of other early civilizations. The mountain itself is composed of carboniferous limestone (calcium carbonate, $CaCO_3$) and the caves are located within a portion of the mountain roughly resembling a conical pyramid (Foyo *et al.,* 2009). The conical pyramid shape would become a staple of Mycenaean and other Mediterranean cultures' funeral rites with the development of the "*beehive tomb*" (θολωτοὶ τάφοι, "*domed tombs*") throughout Greece in the monumental Late Bronze Age, and some evidence exists of beehive tombs in locations as remote as present day Oman (Evans, 1930; Potts, 1997). It may be that the pyramidal shape of Monte Castillo was more than coincidental regarding the choice of this location by the ancient peoples of the Iberian Peninsula. The composition of the rock (limestone) bears a remarkable similarity to the composition of the monumental Pyramids of Giza, constructed primarily of limestone blocks, which is a poor conductor of electricity (Romer, 2007).

The Golden Ratio (Livio, 2008; Keen, 2014, φ = 1.618…) is a geometric relationship which can be expressed algebraically as:

$$\frac{a+b}{a} = \frac{a}{b} = \varphi$$

This ratio can be found throughout the construction of the Pyramids and the mountainous site of Monte Castillo. Using the measurement for the Pyramidal half-base (230.4/2 = 115.2 m) and the length of the side of the Pyramid (186 m), as well as the height of Monte Castillo (354 m) and its radius (220 m), the conspicuous presence of the Golden Ratio within Monte Castillo can be obtained:

$$\frac{115.2\,m + 186\,m}{186\,m} \cong \frac{220\,m + 354\,m}{354\,m} \cong 1.618$$

Furthermore, the approximate end of the spine of Monte Castillo is ~575 m west of the peak, which is related to the radius of the mountain by the Golden Ratio again:

$$\frac{220\,m + (575-220)m}{(575-220)m} \cong \frac{220\,m + 355\,m}{355\,m} \cong 1.618$$

The potential importance of the presence of this mathematical property (φ) within the natural rock outcropping cannot be understated. It has been incorporated into many aspects of Classical architecture including the Parthenon in Athens, suggesting that, to ancient cultures, the Golden Ratio (or more accurately for the contemporary *zeitgeist*, the Divine Proportion), carried with it both symbolic and, perhaps, a functional purpose (Fletcher, 2006; Olsen, 2006). That the Golden Section is present within the cave system of

Monte Castillo, however, may not be a coincidental feature, given the vast evidence of Sacred Geometry from the ancient Egyptians and within many early religious texts such as the Bible, Talmud, and Chinese "*Book of Changes*", which has subsequently found numerous applications in modern theoretical physics (Stakhov, 2006).

However, consideration of the actual physical stimuli associated with important ancient sites presents an even greater number of salient features relevant for exploration within neurotheology. One of the primary enhanced stimuli specifically associated with cave sites would consist of acoustic features produced by the particular geography, geology, and geometry of each individual location. As an example, there are three types of standing waves that can exist in any space. The most powerful are axial, which involve two parallel surfaces. The remaining are less powerful but are nonetheless important and include tangential, involving two sets of parallel surfaces, and oblique, where six surfaces play a role. The frequencies of the axial, oblique, and tangential modes can be calculated as follows:

$$f = (c_s/2) \cdot \sqrt{[\left(\frac{n_x}{X}\right)^2 + \left(\frac{n_y}{Y}\right)^2 + \left(\frac{n_z}{Z}\right)^2]}$$

where f = frequency of standing wave in Hz, c_s = speed of sound (~343 m·s^{-1} at 20°C), n_x = order of the standing wave for room length, n_y = order of the standing wave for room width, n_z = order of standing wave for room height, and X, Y, Z = length, width, and height of room.

Previous archaeoacoustic research at UK "*sacred sites*", which have been associated with significant effects on dream content, revealed an acoustic resonance at 99 Hz and 110 Hz, the baritone range of a human voice (Devereux *et al.,* 2007). Additional research has demonstrated similar acoustic resonance features in the range of 95 to 120 Hz at other megalithic sites, particularly at 110 to 112 Hz (Jahn *et al.,* 1996). One frequency of particular interest seems to be ~110 Hz, for which resonance was also recorded at the Chun Quoit prehistoric monolith in Land's End, Cornwall. The site is known for the prevalence of anomalous phenomena such as bursts of light along with this previously observed 110 Hz acoustic feature (Devereux *et al.,* 2007). This specific frequency range could be particularly relevant to biological function.

The experimental stimulation of laryngeal vibrations through an external device operated at a frequency of 110 Hz has previously revealed a series of marked resonance peaks at 110, 170, and 240 Hz (Švec *et al.,* 2000). Even more relevant to theoretical implications for consciousness and prehistoric spiritual activity are the experimental effects of neuroelectrical activity which have been observed. Research conducted on the effects of frequency-dependent audio tones on brain activity has shown that the 110 Hz band was associated with lower overall left temporal lobe activity and an asymmetric prefrontal shifting from left- to right-hemispheric dominance compared to other frequencies investigated (Cook *et al.,* 2008).

Furthermore, given that acoustic stimuli are pressure waves, resonance within the 110 Hz band could also activate Pacinian corpuscles afferents whose transduction frequency overlaps with this value (Freeman & Johnson, 1982). Signal transduction of 110 Hz into an electromagnetic field through neuronal firing could also induce calcium efflux (Blackman *et al.,* 1985) which is an important biomolecule to cellular homeostasis. Finally, it has been shown that 110 Hz is a fundamental frequency of activity within the CA3 hippocampal region of the brain (Csicsvari *et al.,* 1999; Oliveira & Bading, 2011), an important structure involved in memory, but also implicated in anomalous subjective experience (Persinger, 1983; 1984; Booth *et al.,* 2005; St-Pierre & Persinger, 2006).

The hippocampus may serve as a gateway for religious experience for several reasons, including neurophysiological, neurochemical, and neuropsychological. Neurophysiological evidence is provided by electrophysiological data, which has demonstrated the presence of two distinct states within the hippocampus; one dominated by theta activity (4 to 7 Hz), and the other by the presence of hippocampal waves or fast gamma oscillations (90 to 250 Hz) (Anderson *et al.,* 2006). During arousing stimuli, such as when one navigates their environment or encounters subjective novelty, the theta rhythm dominates. During reduced movement, fast gamma oscillations dominate and resonate in the CA1, CA3, and parahippocampal regions, centered around 110 Hz (Buzsaki & Silva, 2012), and have been implicated in memory consolidation. The selection of ancient sacred

sites and building of megalithic monuments which demonstrate a 110 Hz dominant resonant frequency may not be spurious.

Additionally, it has been well documented that serotonin plays a significant role in the modulation of hippocampal theta and that inhibiting projections from midbrain serotonergic neurons results in the activation of the mesolimbic dopaminergic system (Previc, 2009; Winkleman, 2013). However, the serotonergic inhibition of the mesolimbic dopamine system has other interesting features aside from memory. A decrease in serotonin activity with an increase in dopamine activity is a common feature related to dreaming, out-of-body experiences and hallucinations, and excessive dopaminergic activity within the mesolimbic system is associated with hyper-religiosity (Previc, 2009). More specific to magico-religious and spiritual states, excessive dopamine activity is associated with upward eye movements and hallucinations in the upper visual field (Previc, 2006), and may relate to the fact that many spiritual experiences and beliefs are generally biased in the upward direction. Further support of this can be obtained when considering the opposite neurochemical states, where an increase in serotonergic activity and a decrease in dopaminergic activity results in attentional neglect of the upper visual field, nose-diving behaviour, and an overall decrease in other upwardly oriented behaviours (Blanchard *et al.,* 1997; Previc, 1998).

Consider the geometry of religious and spiritual structures, such as the upwardly projecting pyramids, domes, monasteries, and megalithic structures, along with common cultural themes such as shamans sending spirits to the sky, Moses on Mount Sinai, the Angel Gabriel transporting Mohammed into the sky on a chariot, Heaven as a place somewhere above, and even ancient meditation techniques focusing upward on the "*Third Eye*". Each of these demonstrates an upward bias, and all could potentially be explained by an increase in mesolimbic dopamine activity coupled with a decrease in midbrain serotonin activity. Considering this evidence as a whole, the 110 Hz frequency recorded from multiple sites may act as a "switch" resulting in enhanced dopamine activity and increased spiritual experiences.

These frequency-mediated processes may be involved in the induction of altered states of consciousness or changes in cognitive processing experienced in association with various sacred sites.

Methods

Equipment

A total of 31 audio tones of different frequencies (80 Hz to 1 kHz) were created with the addition of pink noise and a 16 Hz to 20 kHz increasing amplitude sound. Audio was recorded and generated at -3 dB using Pro Tools software. Each frequency file was one minute in duration. For playing audio within the cave site, an amplifier with 15 W output power was employed with a single omnidirectional speaker (8 Ohms, frequency response: 20 Hz to 20 kHz). All files were accessed from a portable USB drive on a laptop computer.

For audio recording within the cave, a condenser microphone was used (Omnidirectional for free field measurement Superlux ECM-999). This device has an O-type omnidirectional polar pattern, with a frequency response of 20 Hz to 20 kHz. Microphone sensitivity was -37 dBv/pa, with a signal-to-noise ratio>70 dB. A StudioSeries analogue-to-digital converter was used to record audio onto a laptop computer with a sampling rate of 16 bit/48 kHz.

Location

Close to the town of Puente Viesgo in the province of Santander, Spain, there are four major caves inside of a local mountain site, Monte Castillo (Figure 1; Iriarte *et al.,* 2009). Within the mountain, there is an expansive labyrinth of caves which were frequented by prehistoric humans (Foyo *et al.,* 2009). These feature many cave drawings and paintings which have greatly contributed to our understanding of our prehistoric ancestors in this area (Valdes *et al.,* 1997; Soto-Barreiro, 2003; Lloret Martine de la Riva & Maillo Fernández, 2006). The oldest known Paleolithic cave painting in the world is contained in this cave system, dating back at least 40800 years (Pike *et al.,* 2012). In total, there are over 275 different figures on the various cave walls, which include images of horses (Figure 2), bison (Figure 3), and others, along with a large number of human hand prints (e.g., Figure 4).

Figure 1. Outside of mountains at Puente Viesgo, housing expansive prehistoric caves.

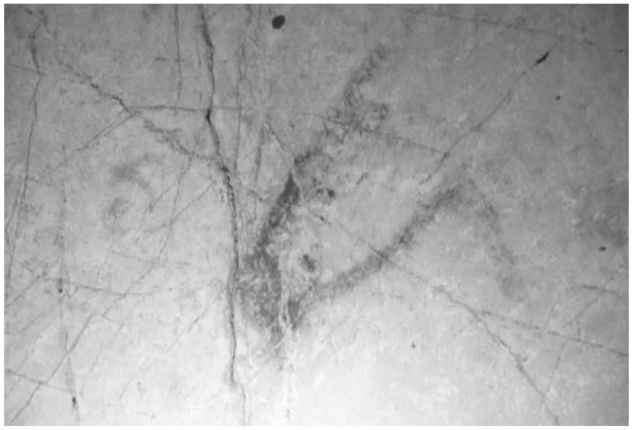

Figure 2. Cave drawing of a horse figure.

Figure 3. Cave drawing of a bison figure.

Figure 4. Cave drawing featuring human hand prints.

Procedure

All materials were placed inside of El Castillo cave and transported to a location where prehistoric peoples are thought to have conducted ritual ceremonies (Arias, 2009). At one side of this chamber, a stalagmite was hand carved by humans to provide a shape in one extreme of the rock resembling a horn (Figure 5). Once illuminated by a candle, a ghostly shade was projected onto the wall (Figure 6). According to archaeological findings, this was the location where the shamans likely engaged in their magico-religious activities, probably generating low frequency sounds with their voice and primitive instruments, as noted in many shamanic rituals of other cultures (Krippner, 2000). This was where the microphone used to emit the audio tones of varied frequencies was installed.

Figure 5. Large carved stalagmite at ritual site.

Figure 6. Shadow cast by carved stalagmite.

In front of this stalagmite, at about 6 m distance, a rock shaped "*anfiteatrum*" provides a natural place for spectators to watch and participate in any event. This is where the recording microphone was placed, in order to imitate what any prehistoric human could hear while seated there. The ceiling of this hall was very irregular, reaching its peak well above the stalagmite (about 10 m) and dropping as low as 1.5 m around the perimeter.

All 31 one-minute frequencies with pink noise and a 16 Hz to 20 kHz increasing amplitude sound were produced from the emitting microphone, while the sounds bouncing off of the "*anfiteatrum*" area were recorded with the receiving microphone. Each frequency was recorded in stereo WAV format using a laptop computer with Cool Edit Pro v2.0 at 32 bit, 44.1 kHz sample rate.

Analysis of cave recordings was conducted using Pro Tools software.

Results

Recordings were analyzed and plotted according to the obtained sound intensity values (dB). A distinct increase in sound level was observed as the frequency of the emitted tone shifted towards the 100 Hz range (Figure 7), reaching a maximum peak at 108 and 110 Hz (-1 dB). This simple finding is remarkably consistent with previous archaeoacoustic investigations of important historic and prehistoric sites (Jahn *et al.,* 1996; Devereux *et al.,* 2007), and may lend further support to the archaeological findings which suggest that this particular cave, El Castillo, was likely employed as a ritual site in the prehistoric world. Furthermore, this could also support theoretical contentions that historically important or sacred sites may have been at least partially chosen based on their potential neuro-modulating properties (Cook *et al.,* 2008).

Discussion

To our knowledge, this is the first experimental demonstration of overlapping acoustic features between the important El Castillo cave and other well-known prehistoric sites (Jahn *et al.,* 1996; Devereux *et al.,* 2007), particularly regarding the 110 Hz frequency-dependent sound amplification revealed. Furthermore, the potential effects of specific sonic stimuli associated with many of these locations to alter physiology, especially neuroelectrical activity (Cook *et al.,* 2008; Hill & Saroka, 2010), has been demonstrated by previous research. The fact that this sonic frequency range consistently appears to be a consistent feature within resonance and other acoustic properties at many culturally important sites, including the El Castillo caves, could suggest something fundamental about this specific component in the context of spiritual activity and neurotheology.

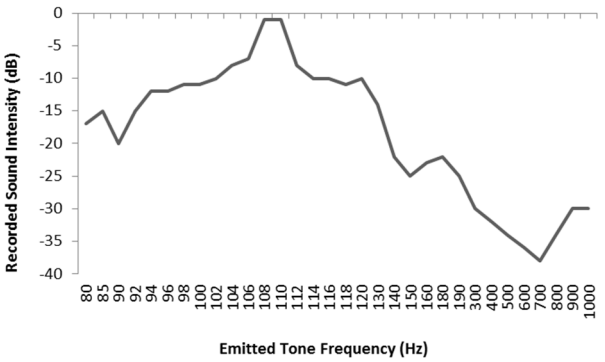

Figure 7. Intensity (dB) of sound recorded from the location of the "anfiteatrum" area associated with audio emissions at each frequency (Hz).

Particle displacement (ξ) refers to a measurement of distance in the movement of particles as a wave. It can be derived by dividing the particle velocity (v) as the speed of sound, or 343 $m \cdot s^{-1}$, by the angular frequency (ω) of the wave ($2 \cdot \pi \cdot f$). For a wave with a periodicity equivalent to 108 Hz, the particle displacement, assuming 20°C, is $5 \cdot 10^{-1}$ m or approximately 50.55 cm. The particle displacement is slightly decreased for a 110 Hz frequency at 49.63 cm. The relevance of this distance as particle displacement is only apparent when the dimensions of the archaic *H. sapiens* skull are inferred. Ruff *et al.* (1997) reported that the cranial capacity of late archaic (36 to 75 kyr BP) *H. sapiens* as approximately 1498 ± 45 cc based upon N = 14 measurements. Assuming a sphere, the radius of the cranial vault is the cubed root of the product of the volume of the cranial vault divided by π, multiplied by ¾, from which a radius of $5.8 \cdot 10^{-2}$ m or a diameter of $11.6 \cdot 10^{-2}$ m is derived. Accounting for an additional 2 cm associated with additional tissue (*e.g.,* meninges, vasculature, bone, scalp, etc.) between the lateral surface of the head and the cranial vault, or the space within which the brain rests, the circumference ($2 \cdot \pi \cdot r$) of an archaic *H. sapiens* skull would be 49 cm.

Both the diameter and the circumference of the skull are within the same order of magnitude as the particle displacement associated with the peak frequencies measured within the cave spaces previously discussed. With minor variations in air temperature and cranial morphology, this convergence in particle displacement and cranial dimensions will have accommodated the majority of skulls to enter the cave spaces within Monte Castillo. Sonically-induced changes in brain activity have been reported for frequencies above $2 \cdot 10^4$ Hz (Tufail *et al.,* 2011), however, very low frequency oscillations above auditory threshold have not been thoroughly examined.

Sound energy density in $J \cdot m^{-3}$ is the quotient obtained when dividing intensity as power ($W \cdot m^{-2}$) by the speed of sound. The recordings at El Castillo specifically revealed a -1 dB peak in intensity of the stimulus, corresponding to a unit power of $7.9 \cdot 10^{-13}$ $W \cdot m^{-2}$. The sound energy density, assuming a speed of 343 $m \cdot s^{-1}$ for the sound wave, is $2.3 \cdot 10^{-15}$ $J \cdot m^{-3}$. To obtain energy, the energy density must be multiplied by a volume. Using the aforementioned volume of the late archaic *H. sapiens* cranial vault, or $1.5 \cdot 10^{-3}$ m^3, the total energy of the wave within the medium of the vault proper is $3.5 \cdot 10^{-18}$ J. Persinger (2014) examined the effects of infrasound on human health and argued that it is the pattern of the stimulus rather than the type of stimulus which might influence biological processes assuming a mechanism of resonance.

If the calculated energy were electromagnetic, a wavelength (λ) could be derived by dividing the product of Planck's constant ($6.63 \cdot 10^{-34}$ $J \cdot s^{-1}$) and the speed of light ($\sim 3.0 \cdot 10^8$ $m \cdot s^{-1}$) by the energy of the wave or $3.5 \cdot 10^{-18}$ J. The wavelength obtained is $5.6 \cdot 10^{-8}$ m or approximately 57 nm. The derived wavelength of this electromagnetic wave falls within the spectrum of ultraviolet (UV) light with a value within the same order of magnitude as the cell membrane (10 nm). Cells are known to emit and respond to emissions of electromagnetic energy with periodicities and associated energies equivalent to those of ultraviolet light (Popp, 1979). The membrane width itself is an important boundary condition associated with biophotonic communication (Dotta *et al.,* 2011).

A 110 Hz pressure wave has an associated acceleration of $3.7 \cdot 10^4$ $m \cdot s^{-2}$ which is derived by multiplying the frequency of the wave by the speed of sound. Applied over the mass of the late archaic *H. sapiens* brain, the resulting unit would be in kg $m \cdot s^{-2}$ or a Newton (N). Ruff *et al.* (1997) report a brain mass of $0.14 \cdot 10^{-1}$ kg which, multiplied by the wave acceleration, gives 518 N of force. A force in N applied over a unit distance gives energy in joules (J). The amount of electromagnetic energy necessary to stimulate the entire cerebral cortex is equivalent to the energy of an action potential ($\sim 2 \cdot 10^{-20}$ J) multiplied by the

number of neurons which comprise the cortex ($\sim 10^{11}$). The energy obtained is $\sim 2 \cdot 10^{-9}$ J, which is approximately equivalent to 518 N of force applied over a distance of 10^{-11} m, yielding an energy value of $5.2 \cdot 10^{-9}$ J. This unit of distance is within a decimal place of the Bohr radius ($5.3 \cdot 10^{-11}$ m) which is the typical distance between the proton and electron in a hydrogen atom. In other words, the unit force of the wave applied over the most fundamental geometry of the largely hydrogen-based brain would yield energy sufficient to stimulate the entirety of the cerebral cortex.

That even incredibly minute environmental energies are capable of affecting physiological systems is not unknown in the physical sciences (Persinger, 2014; Saroka *et al.*, 2014), and the potential for ancient "*sacred*" sites with markedly similar acoustic features to induce neuroelectrical changes at the level of the cell are not outside the realm of possibility. As demonstrated by the preceding discussions, there are a myriad of potential sources of influence associated with the sonic effects often identified at these important prehistoric sites. It is worth further investigation of these conspicuously overlapping findings in order to better determine the effects of the specific geometric and subsequent acoustic properties of these sites on the potential development of human consciousness and spiritual belief systems consistent with neurotheological approaches to ritual and religious experience.

References

Anderson P, Morris R, Amaral D, Bliss T, O'Keefe J. The Hippocampus Book. New York, NY: Oxford University Press, 2006.

Arias P. Rites in the Dark? An Evaluation of the Current Evidence for Ritual Areas in Magdalenian Cave Sites. World Archaeo 2009; 41(2): 262-294.

Blackman CF, Benane SG, House DE, Joines WT. Effects of ELF (1–120 Hz) and Modulated (50 Hz) RF Fields on the Efflux of Calcium Ions from Brain Tissue i*n Vitro*. Bioelectromagnetics 1985; 6(1): 1-11.

Blanchard RJ, Griebel G, Guardiola-Lemaitre B, Brush MM, Lee J, Blanchard DC. An Ethopharmacological Analysis of Selective Activation of 5-HT1A Receptors: The Mouse 5-HT1A Syndrome. Pharma Biochem Behav 1997; 57: 897–908.

Booth JN, Koren SA, Persinger MA. Increased Feelings of the Sensed Presence and Increased Geomagnetic Activity at the Time of the Experience during Exposures to Transcerebral Weak Complex Magnetic Fields. Int J Neurosci 2005; 115(7): 1053-1079.

Buzsaki G and Silva F. High Frequency Oscillations in the Intact Brain. Prog Neurobio 2012; 98: 241-249.

Cook IA, Pajot SK, Leuchter AF. Ancient Architectural Acoustic Resonance Patterns and Regional Brain Activity. Time Mind 2008; 1(1): 95-104.

Csicsvari J, Hirase H, Czurkó A, Mamiya A, Buzsáki G. Fast Network Oscillations in the Hippocampal CA1 Region of the Behaving Rat. J Neurosci 1999; 19(RC20): 1-4.

Debertolis P and Bisconti N. Archaeoacoustics Analysis and Ceremonial Customs in an Ancient Hypogeum. Socio Study 2013; 3(10): 803-814.

Devereux P, Krippner S, Fish A. A Preliminary Study on English and Welsh "Sacred Sites" and Home Dream Reports. Anthro Consc 2007; 18(2): 2-28.

Dotta BT, Buckner CA, Cameron D, Lafrenie RF, Persinger MA. Biophoton Emissions from Cell Cultures: Biochemical Evidence for the Plasma Membrane as the Primary Source. Gen Physio Biophys 2011; 30(3): 301-309.

Evans A. The Shaft-Graves and Beehive-Tombs of Mycenae. J Hellenic Stu 1930; 50: 337.

Faulkner CH, Deane B, Earnest Jr HH. A Mississippian Period Ritual Cave in Tennessee. Amer Antiq 1984; 49(2): 350-361.

Fletcher R. The Golden Section. Nexus Net J 2006; 8(1): 67-89.

Foyo A, Sanchez MA, Tomillo C, Iriarte E. El Castillo Mountain Prehistoric Caves (Cantabria, North of Spain): Structural Geology, Karstic Development and Prehistoric Art Manifestations. Proc 3rd IASME/WSEAS Int Conf Geol Seismo 2009: 148-152.

Freeman AW and Johnson KO. Cutaneous Mechanoreceptors in Macaque Monkey: Temporal Discharge Patterns Evoked by Vibration, and a Receptor Model. J Physio 1982; 323(1): 21-41.

Hill DR and Saroka KS. Sonic Patterns, Spirituality and Brain Function: The Sound Component of Neurotheology. NeuroQuantology 2010; 8(4): 509-516.

Iriarte E, Foyo A, Sánchez MA, Tomillo C, Setién J. The Origin and Geochemical Characterization of Red Ochres from the Tito Bustillo and Monte Castillo Caves (Northern Spain). Archaeometry 2009; 51(2): 231-251.

Jahn RG, Devereux P, Ibison M. Acoustical Resonances of Assorted Ancient Structures. J Acoust Soc Amer 1996; 99(2): 649-658.

Keen JS. Two-Body Interaction, Bifurcation, Chaos, Entanglement, and the Mind's Perception. NeuroQuantology 2014; 12(2): 262-275. DOI: 10.14704/nq.2014.12.2.711

Krippner S. The Epistemology and Technologies of Shamanic States of Consciousness. J Consc Stu 2000; 7(11-12): 93-118.

Livio M. The Golden Ratio: The Story of Phi, the World's Most Astonishing Number. Random House LLC 2006.

Lloret Martíne de la Riva M and Maíllo Fernández JM. (2006). Aproximación Tecnológica a los Niveles 18b, 18c y 16 de la Cueva de El Castillo (Puente Viesgo, Cantabria). In En el Centenario de la Cueva de El Castillo. Centro Asociado a la UNED en Cantabria 2006: 493-512.

Mazmudar S and Mazmudar S. Religion and Place Attachment: A Study of Sacred Places. J Enviro Psych 2004; 24(3): 385-397.

Metzner R. Transformation Processes in Shamanism, Alchemy, and Yoga. In S Nicholson (ed.) Shamanism: An Expanded View of Reality (pp. 233-252). Wheaton, Illinois: Quest Books 1987.

McNatt L. Cave Archaeology of Belize. J Cave Karst Stu 1996; 58(2): 81-99.

Oliveira AM and Bading H. Calcium Signaling in Cognition and Aging-Dependent Cognitive Decline. Biofactors 2011; 37(3): 168-174.

Olsen S. The Golden Section: Nature's Greatest Secret. Bloomsbury Publishing USA 2006.

Persinger MA. Religious and Mystical Experiences as Artifacts of Temporal Lobe Function: A General Hypothesis. Percept Mot Skills 1983; 57: 1255-1262.

Persinger MA. Striking EEG Profiles from Single Episodes of Glossolalia and Transcendental Meditation. Percept Mot Skills 1984; 58: 127-133.

Persinger MA. Infrasound, Human Health, and Adaptation: An Integrative Overview of Recondite Hazards in a Complex Environment. Nat Hazards 2014; 70(1): 501-525.

Pike AWG, Hoffmann DL, García-Diez M, Pettitt PB, Alcolea J, De Ralbín R, González-Sainz C, de la Heras C, Lasheras JA, Montes R, Zilhão J. U-series Dating of Paleolithic Art in 11 Caves in Spain. Science 2012; 336(6087): 1409-1413.

Popp FA. Photon Storage in Biological Systems. In Popp FA, Becker G, Konig HL, Pescha W (eds.) Electromagnetic Bioinformation (pp. 123-149). Urban and Schwarzenberg: Munich 1979.

Potts D. Rewriting the Late Prehistory of South-Eastern Arabia: A Reply to Jocelyn Orchard. Iraq 1997; 59: 63-71.

Previc F. The Neuropsychology of 3-D Space. Psych Bulletin 1998; 124: 123–164.

Previc FH. The Role of the Extrapersonal Brain Systems in Religious Activity. Consc Cog 2006; 15(3): 500-539.

Previc F. The Dopaminergic Mind in Human Evolution and History. New York, NY: Cambridge University Press 2009.

Romer J. The Great Pyramid: Ancient Egypt Revisited. Cambridge University Press: Cambridge 2007.

Ruff CB, Trinkaus E, Holliday TW. Body Mass and Encephalization in Pleistocene *Homo*. Nature 1997; 387: 173-176.

Saroka KS, Caswell JM, Lapointe A, Persinger MA. Greater Electroencephalographic Coherence Between Left and Right Temporal Lobe Structures during Increased Geomagnetic Activity. Neurosci Lett 2014; 560: 126-130.

Soto-Barreiro MJ. Cronología Radiométrica, Ecología y Clima del Paleolítico Cantábrico. Monografías 19, Museo Nacional y Centro de Investigación de Altamira 2003.

St-Pierre LS and Persinger MA. Experimental Facilitation of the Sensed Presence is Predicted by the Specific Patterns of the Applied Magnetic Fields, Not by Suggestibility: Re-Analyses of 19 Experiments. Int J Neurosci 2006; 116(19): 1079-1096.

Stakhov A. The Golden Section, Secrets of the Egyptian Civilization and Harmony Mathematics. Chaos Solitons Fractals 2006; 30(2): 490-505.

Švec JG, Horáček J, Šram F, Vesely J. Resonance Properties of the Vocal Folds: *In Vivo* Laryngoscopic Investigation of the Externally Excited Laryngeal Vibrations. J Acoust Soc Amer 2000; 108(4): 1397-1407.

Tufail Y, Yoshihiro A, Pati S, Li MM, Tyler WJ. Ultrasonic Neuromodulation by Brain Stimulation with Transcranial Ultrasound. Nature Protocols 2011; 6(9): 1453-1470.

Valdés VC, Gómez MH, de Quirós FD. The Transition from the Middle to the Upper Paleolithic in the Cave of El Castillo (Cantabria, Spain). In Clark GA and Villermet CM (eds.) Conceptual Issues in Modern Human Origins Research (pp. 177-188). Walter de Gruyter, Inc: New York 1997.

Whitley DS. Shamanism and Rock Art in Far Western North America. Cambridge Archaeo J 1992; 2(1): 89-113.

Winkleman M. Shamanism in Cross-Cultural Perspective. Int J Transpers Stu 2013; 31(2): 47-62.