Research Essay

Solving the "Hard Problem": Consciousness as an Intrinsic Property of Magnetic Fields

Todd Murphy*

Abstract

The "hard problem," the question of the physical basis of consciousness, finds a solution in the hypothesis that consciousness is an attribute of magnetic fields, and that complex consciousness (which can include 'self-awareness', intelligence, or social interaction) is based on the integration of the brain's magnetic field (originating from its rich population of magnetite crystals) with its neural electrical system. This hypothesis simplifies the local vs. non-local question, redefines "mind-body" dualism, as well as possibly resolving the anomaly of unpredictably sophisticated behaviour in anencephalics. One of its consequences is a rejection of behaviorism and solipsism. Difficulties in falsification and approaches to corroboration are discussed, as well as challenges that face a rigorous working definition of the phenomenon, essential for experimental validation.

Keywords: Consciousness, hard problem, magnetic field, mind-body, neural, electric system.

It's widely assumed that consciousness is the phenomenological correlate of a specific process or processes in the brain. Resolving the problem of how consciousness, which we mean as *the capacity for subjective experience*, appears as a result of brain function (the "hard problem"), is one of the defining questions of contemporary neuroscience. Here, we propose that consciousness is an intrinsic property of magnetic fields. This implies that even a single common magnet would possess a rudimentary consciousness. A natural corollary is that cognitive complexity relies on structural or functional complexity in the magnetic field that supports it.

The word "consciousness" presents a dilemma. There is no objective proof of its existence, in spite of its subjective immediacy. All definitions that encompass the phenomenon are inherently tautological. In our definition, *the capacity for subjective experience*, the word "subjective" is tautological with "conscious," and the same is true for the word *experience*. Subjectivity is predicated on consciousness, but one cannot be conscious of anything in the absence of subjective experience. The solution to the circular reasoning inherent in defining consciousness is to introduce a postulate (or "axiom"), a deliberate and overt assumption made to facilitate our discussion. Here, we assume is that the introspective experience of subjectivity that normal humans report is generalizable to other people and members of other species, and that all instances of consciousness have the same basis. This axiom allows us to treat consciousness, a subjective phenomenon, as an objective one.

* Correspondence: Todd Murphy, Associate Researcher, Behavioral Neuroscience Program, Laurentian University, Canada.
E-Mail: brainsci@jps.net

Known brain functions rely on electrical, chemical, histological and other systems. However, no known actions or interactions of these systems have been able to account for the phenomenon of subjective awareness.

Figure 1. Example of a magnetotactic bacteria showing a magnetosome.

The brain's densely distributed magnetite crystals[1] may function as the substrate for another neural system. This "magnetite biomineralization in the human brain" consists of five million magnetite crystals per gram of brain tissue. They appear to have formed there, and aren't absorbed from the environment. These crystals are arranged in chains called *Magnetosomes*. They're also found in a wide range of species, including birds, fish, mammals, and bacteria.

One researcher in this field has proposed a mechanism where magnetic fields might influence brain tissues and electrical activity.

> "A simple calculation shows that magnetosomes moving in response to earth-strength ELF fields are capable of opening trans-membrane ion channels, in a fashion similar to those predicted by ionic resonance models. Hence, the presence of trace levels of biogenic magnetite in virtually all human tissues examined suggests that similar biophysical processes may explain a variety of weak field ELF bioeffects." [2]

As described in Maxwell's Equations, axonal electrical currents generate low-intensity magnetic fields, which will induce movement in nearby magnetosomes, and disseminate their firing patterns to all other magnetosomes in the brain through magnetic resonance (a field-to-field effect).

The seven billion magnetite crystals in an average brain, and the magnetosomes they comprise, produce multiple fields, but they're also components of the brain's larger magnetic field, with two (hemispheric) loci, and constantly changing regions of peak magnetic field strength. We propose that consciousness is a property of this magnetic field, and the functions associated with regions of peak magnetic field strengths or the most salient magnetic information will correlate with the content of consciousness. This agrees with the principle that the phenomenology of the most metabolically active neural regions (in either excitation or inhibition) correlate with the present content of the 'mind'.

The Primary Characteristic of Consciousness

The primary characteristic of consciousness is its role in the subject/object relationship i.e., perception and response. Thus, even the most rudimentary awareness would be enabled with feedback loops.

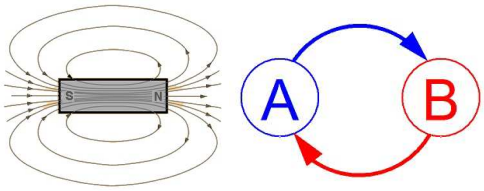

Figure 2. Feedback exists between two parts when each affects the other.

Two magnetic poles, whether they comprise the sole source of a magnetic field, or are only one of many, can supply a model for a hypothetical 'rudimentary' consciousness.

An example of simple feedback appears in figure 2, where an informational feedback loop is shown next to a simple magnetic field. The similar structure of the theoretical feedback loop and the actual lines of force is obvious. Electrical activity, such as neuronal pulses, bursts, and oscillations, as well as input from background magnetic fields, would continually complicate the neural field, making *simple* feedback loops unlikely.

Any anisotropisms in the magnetic or electrical background would disturb the uniformity of the neural magnetic field, and pulsing axonal electrical current will produce pulsing magnetic fields, introducing its information content into the system.

In Figure 3, we see an analogous feedback loop with two inputs and one output. A magnetic general feedback loop, unlike the informational one shown schematically, would feed back to all nearby field sources, so that it might not have a single discernable direction of communication or dedicated inputs and outputs.

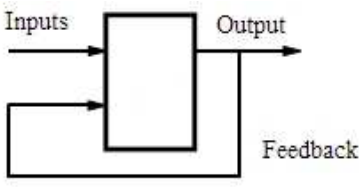

Figure 3. A schematic representation of a theoretical general feedback loop.

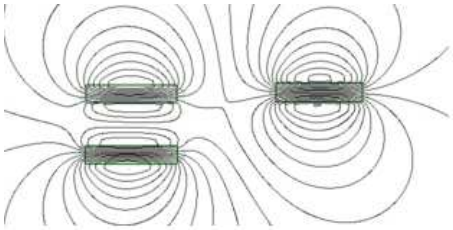

Figure 3a. The same feedback loop as a magnetic field from three magnetosomes, much more complex than either its schematic or a single magnet.

Complex magnetic fields, produced by larger numbers of magnetosomes, would be capable of transmitting significant amounts of information. The greater the complexity of the resulting field, the more information it could bear. Neural magnetite has already been rigorously hypothesized to have informational storage capabilities[3]. The structure of the resulting magnetic fields would have a complexity analogous to a Newtonian 'three-body' system (Fig. 4). The inevitable pulsations and bursts from neural firing will further complicate the internal structure of such a magnetic field. Although a precise exploration of the topic is outside the scope of this paper, holographic information storage and processing should not be ruled out.

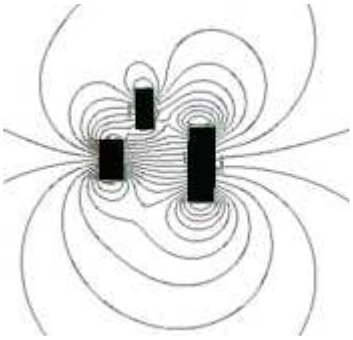

Figure 4. A magnetic 'three-body' system.

Biological consciousness is characterized by its ability to perceive and respond to qualia and percepts from multiple sensory, affective and cognitive modalities, localized to specific regions and networks in the brain. When the content of our consciousness is dominated by a somatic percept or task, for example, the corresponding neural regions (parietal strip, basal ganglia, cerebellum, etc) are subject to greater or more novel electrical activity, creating corresponding fluctuations in the magnetic field in the same region, as observed by Brenner (et. al) in 1978[4]. Specific fluctuations might encourage attentional mechanisms to advert to the somatic phenome. It seems reasonable to suppose that the *content of consciousness* as well as the present *state of consciousness* derive from more localized neural electrical and chemical activity. Magnetic information would, in principle, be able to simultaneously inform all brain regions of any stimulus that demands a change of state in consciousness, facilitating rapid changes in behavior in response to threats or opportunities.

In simpler terms, consciousness (the brain's magnetic field) is constantly influenced by neural electrical activity through the classically-known relationship between magnetic fields and electrical currents. Maxwell's equations thus offer a mathematical description of the primary

interface between "mind and matter", but not the mind's overall *behavior*. What we experience in each moment may be the phenomenological correlate of this field's most excited, coherent, or information-rich areas or the regions with the most salient information content.

Elsewhere[5], I have pointed out that magnetic fields are propagated through the brain significantly faster than neuroelectrical or neurochemical processes. This makes magnetic field communication within the brain the fastest type available. Organisms will respond to threats and opportunities more rapidly if the basis of consciousness were in the brain's magnetic substrate than if it were based on the slower chemical or electrical processes.

The two poles of a simple magnetic field provide a straightforward, but simplified, model for the subject/object relationship. More complex magnetic systems provide a basis for more complex consciousness, such as is found in all species with developed nervous systems. "Self-awareness" (often confused with consciousness) may be little more than a feedback loop between the junctures for sensory, cognitive, and affective functions (in the thalamus), and the sense of self.

Emergentism

Consciousness has been hypothesized to be an emergent property of brain activity[6] ("emergentism"). An emergent property of a system is said to be dependent on the system, but displaying phenomena or behavior that can't be predicted by the behavior of its components ("synergy"). Alternately, the whole system has properties that its constituents lack, so that in emergentism, consciousness is a feature of brain activity, but not of any specific neural process or system. Our view differs in proposing that consciousness is specifically attributable to magnetic fields in the brain, though this doesn't exclude the interpretation that consciousness is an emergent property of magnetic fields.

Evolutionary Aspects

It seems possible that the brain's electrical system evolved in support of its magnetosomal system. The first neural electrical activity may have appeared after species began to incorporate magnetite into their tissues. Chains of magnetite crystals could have constituted the very earliest precursor to the nervous systems we now see in all fauna. Indeed, there are simple bacteria, without a nervous system, that use magnetosomes to orient themselves with respect to the geomagnetic field[7] (see fig. 1).

The notion that consciousness is an intrinsic property of magnetic fields implies that *complex* consciousness (including a repertoire of states of consciousness, emotions, cognition, or the capacity for self-awareness) appears in association with complex magnetic fields, which receive information from the brain's electrical system.

Conscious nervous systems may have initially evolved in conformity with the physics of magnetic fields. Consciousness, understood as an attribute of living organisms, is firstly an evolutionary adaptation that contributed to the survival of species on earth. It may not be an emergent property of the brain. Rather, the brain may provide on organic substrate for its magnetic information system, allowing organisms to derive adaptive value from it. The brain as

we know it could be thought of as an extension of its magnetosomes, appearing over time in response to evolutionary pressures. Species with nervous systems that didn't use magnetic fields efficiently, including any information they might store or transmit, would not have been as successful as those that did.

It seems unlikely that human evolution would have found no advantage in exploiting magnetically-carried information in our environment.

A Magnetic Sense

The earth's magnetic field is one of the environmental conditions in which all biological evolution occurs. Many species are known to be sensitive to magnetic fields, including birds, fish, and humans. There is ample evidence that the human nervous system responds to low-intensity magnetic fields[8,9], but there has been controversy about whether humans possess a "magnetic sense". A recent study, however, has uncovered evidence that at least some people can sense changes in the earth's magnetic field[10].

It's possible that humans can sense magnetic fields, but that its specific percepts present themselves synesthetically, "referred" to other senses, cognitions, or affects. It may not be a discreet sensory modality ("magnetoreception") in itself, making the direct perception of magnetic fields an uncommon, but not impossible skill[11]. It may be not unlike the way we see perfect pitch only in people with greater sensitivity to the nuances of sounds. Sensitivity to changes in ambient magnetic fields would be expected to vary between individuals. Interestingly, this kind of "secondary" perception of magnetic fields has been observed with magnetic field stimulation in association with LSD[12].

Local and Non-Local Consciousness

Our hypothesis implies that, as their fields interact, some or all of the information content (its "magnetic signals") of a single consciousness may be shared both with others, and with the geomagnetic field around us[13] through magnetic resonance. Interactions with other human neural magnetic fields would make consciousness a local system with nonlocal functions. It's as though every brain has outposts in every other brain around it. Many of the seeming anomalies and paranormal phenomena that the concept of non-local consciousness attempts to address can be resolved as simple instances of interactions between the magnetic signals in more than one brain and/or the geomagnetic environment. Moreover, in our model, the earth's magnetic field, in which all brains are immersed, is also conscious, and interacts subtly with all brains within it. Each instance of consciousness is individuated, but also integrated with other fields, and able to share any information encoded in them. It's quite likely that signals "written onto" the brain's magnetic fields by its electrical activity would occur in all human brains, because we all share the same evolutionary history, and because electroencephalography has empirically found that specific neural electrical patterns reflects the same activity and states of consciousness in all people, with a few pathological exceptions. Further, because all nervous systems evolved in the medium of the geomagnetic field, we can reasonably expect that neuromagnetic information would incorporate some of its 'codes'. If the signals in neuromagnetic fields are the same for all

humans, then at least some human brains have the potential to directly communicate with each other, though we should not expect that all brains will be equally sensitive to this subtle stimulus.

The Schumann resonance might serve as a carrier frequency for magnetic information transmitted between brains. The resonant frequency for the human brain, based on its circumference and bulk velocity of action potentials, is within the same frequency range as the intrinsic (Shumann) resonance of the Earth's atmosphere[14]. However, the obvious adaptive value of direct neural communication between individuals doesn't exclude perception of other information from within the geomagnetic field, if it's sufficiently coherent or resonant with neuromagnetic patterns, and also carried with a field strength low enough to interact with the brain's magnetic fields. Both magnetic solitons[15] and Hilbert spaces[16] have been proposed as mechanisms for the preservation of neural information in the geomagnetic field.

We would expect 'telepathic' skills and communication, to have had a significant adaptive value in non-verbal social species, including humans[17], prior to our evolution of language, particularly with respect to states of consciousness that facilitate bonding. Our hypothesis here suggests that brain-to-brain ("telepathic") communication and synchronization, as seen in mice[18], bats[19] and humans[20], may be explained as magnetic signals shared by two or more brains, and there has been research in this kind of information sharing[21] [22]. Investigating brain-to-brain communication and its evolution might replace the long-standing emphasis on individual people with reported exceptional skills in some paranormal studies. A single study on brain-to-brain communication in nonhuman primates might do more to elucidate such faculties than a host of case histories with putative psychics. One relevant study has already been published[23].

We should note that, although we refer to the brain's one magnetic field, it can also be worthwhile to regard the magnetic field within each hemisphere as a discreet entity, each exchanging magnetic signals with the contralateral hemisphere, along with their known electrical and chemical communication. Magnetic signals, resonating with electrical signals in the brain, have three properties that would facilitate brain-to-brain communication. First, Maxwell's equations dictate that magnetic shielding of any kind is not possible; magnetic fields cannot be "blocked." Second, magnetic fields, and any signals they might carry, pass through the skull without attenuation[24]. Third, although the field strength may diminish with the inverse square of the distance, information embedded in it can remain intact over substantial distances. "Receiving" information either from other brains, or the geomagnetic field, may rely more on sensitivity to the information than to the magnetic field that carries it. The possibility that there are mechanisms to receive specific magnetic signals, analogous to chemical receptors for specific chemicals, should not be dismissed.

The Interface between Consciousness and Matter

Any viable theory of consciousness must explain how it interacts with matter, including neural tissues, networks, and structures that process sensory information.

The interface of "mind and body" lies in the interaction of magnetic fields and electrical activity in the brain, as described in Maxwell's Equations. Patterns of activity in the brain's electrical system will resonate throughout its magnetic system. The many patterns of neural electrical

firing thus reflect an equally diverse set of magnetic signals. Any magnetic signals produced by even a single magnetosome could be detected by all of them, although they may not all be equally responsive all signals. Groups of neurons that produce a specific electrical signal will be more responsive to the same signal, delivered by a magnetic field, than groups of neurons that don't use it.

Dualism and Non-Dualism

There is a long-standing debate concerning whether consciousness arises from a physical process, or if can exist without a material substrate. Our hypothesis implies that neither of these is the case. To make this explicit, we must return to the basic definitions for matter and energy (mass). We accept special relativity, which tells us that matter and energy are interconvertible. We also reject the notion that consciousness is "matter" insofar as it's not a material substance, so it's more useful to look only at the definition for energy.

"Energy" is the capacity of the body or system enabling it to do *work*. "Work" is anything that alters or tends to alter the point of application of a *force*. A "force" is anything that alters or tends to alter a body or system's state of uniform motion in a straight line or "rest" (*inertia)*.

Magnetism is a *force*, like gravitation. In classical physics, it's neither matter nor energy, but at the same time, it doesn't exist independently of them. The question of whether or not consciousness is a material property depends entirely on whether the definition for matter includes fundamental forces. If we define mass and "material" so that these words encompass *all* their properties, then consciousness is a material phenomenon. If we adhere to the classical definitions for *energy*, *matter* and *forces*, then consciousness is nonmaterial.

The "dualism" debate appears to assume that, if consciousness is a material phenomenon, it must be an expression of material processes. Given that the only instances of consciousness available for scientific study appear in association with living organisms, it seems prudent to suppose (remembering our initial postulate) that the kind of consciousness human beings report is sensitively dependent on biological, and thus material, systems. Our hypothesis doesn't mean that consciousness is a material phenomenon. Rather, it implies that it can only exist in association with matter. Without a central mass, you can't have a gravitational field, but mass and gravitation aren't the same thing. Consciousness might prove to be similarly integrated with magnetic field sources. However, we should not assume that the association between magnetism and matter is one of causality, and avoid drawing the conclusion that matter creates consciousness, or vice versa.

One of the driving forces behind the materialist/dualist/monist debate is the assumption that, if consciousness is material, then it will cease to exist when its host organism dies. However, given that all consciousness on earth exists in the medium of the earth's magnetic field, it's not impossible that neural information can continue after death, preserved in that medium. This author has explored that possibility in another publication[25]. We should note that the present hypothesis does not elucidate the question of the existence of the soul, as it's traditionally conceived.

The Quantum Mechanics of Consciousness

Any quantum-level basis for consciousness would only be an instance of a larger quantum basis for all magnetic fields, and any quantum mechanics of consciousness would resolve into special cases of the quantum mechanics of magnetic fields.

The Anomaly of Anencephalics

The notion that consciousness is a magnetic phenomenon may explain a well-known anomaly in neuroscience. Near-normal cognitive and motor functions in people with significantly-reduced neural tissue ("anencephalics") have been reported in the literature. In one instance, a man with a very small amount of neural tissue, massive ventricular enlargement, and a cranium filled with cerebrospinal fluid (CSF), has been observed to display normal social functioning[26].

Magnetite has been found in CSF[27]. If consciousness is a property of magnetic fields, then magnetosomes in this patient's cerebrospinal fluid would allow him to function within certain limits (his verbal IQ is only 16% below normal), with greatly reduced brain tissue which would still supply signals from its neuronal activity, though perhaps with lower field strengths. In other cases[28] [29] [30], patients largely without a cerebellum have been observed to display only moderate motor deficits. Their cerebellar spaces are also filled with CSF. Their greater than predictable motor functions may be explained as a function of magnetosomes in the cerebrospinal fluid informed by electrical signals from remaining cerebellar tissue. While this fluid undergoes pulsations, it has a nearly zero net flow[31], and a viscosity approaching that of water, which would allow magnetosomes in the cerebellar space to retain a degree of stability and possibly subsume normal cerebellar activity. The present hypothesis would be strengthened if anencephalic's CSF magnetosomes were found to display differences from those of normal CSF.

However, mapping the localization of functions in the remaining neural tissue might reveal that the functions normally found in intact brains are also present, but differently localized, in which case our hypothesis would not be impacted. Of course, such surgery would be very intrusive, and outside the bounds of ethical practice. The anencephalic's intact functions may be a case of accommodation, not unlike what we see in recovery from open-head injuries and following the surgical removal of brain tissue, as in brain cancer, epilepsy, head injuries, etc., but occurring during development. A study of magnetite structures, concentrations, and distributions in an anencephalic's CSF might yield data relevant to the present hypothesis.

Corroboration and falsification

The hypothesis would be strengthened should individuals appear with lower or higher than normal concentrations of magnetite in neural tissue, and were found to exhibit neural deficits or surfeits.

We can reasonably posit that there is a Weber value (or threshold) where enough repetitions or resonation of a magnetic signal throughout the brain will trigger attentional mechanisms to advert to the stimulus (endogenous or external) it represents, bringing it into conscious experience. We would expect Event Related Potentials (ERPs) to play a significant role in this process. Any measurable effects obtained through stimulation of the brain with a typical ERP signal, embedded in a magnetic field (such as enhancing or suppressing response to other stimuli, including other magnetic stimulation), presented with a field strength low enough to interact with the brain's own magnetic fields, would tend to support our hypothesis.

The hypothesis would also be strengthened if a method for imaging small and rapid changes in the amplitudes of the fields surrounding neural magnetosomes were developed and found unique magnetic signals in regions known to associate with consciousness, such as the reticular formation[32],[33], the claustrum[34], and the "posterior cortical hot zone".[35] Differences in local concentrations, organization, or function in the magnetosomes in these areas would also tend to support our hypothesis.

This hypothesis makes predictions that can be corroborated, though reliable procedures for it's falsification it may prove difficult to develop, given the current state of neuroscience. Specific difficulties arise from the tautological nature of definitions for the word *consciousness*, the exclusively subjective nature of consciousness, as well as difficulties involved in separating magnetic field effects, arising from magnetosomes, from those produced by neural electrical activity.

Self, Sense of Self, and States of Consciousness Are Not Consciousness Itself

Some putative attributes of consciousness may in fact be aspects of the sense of self. The criteria for tests must be rigorously defined and narrowed to include only the capacity for subjective awareness. For example, one vernacular science magazine[36] said "…consciousness has to involve the integration of activity from several brain networks, allowing us to perceive our surroundings as one single unifying experience rather than isolated sensory perceptions". This function is known to occur in the thalamus, and may contribute more to the sense of self than the phenomenon of subjective experience *per se*. We should note that 'perceiving our surroundings' for human beings will include events and percepts (such as a single word) where *social* salience and meaning predominate over sensory impact.

In addition, some putative aspects of consciousness are actually mechanisms for managing states of consciousness (e.g. selecting the present object of attention), and affect what we are aware *of*, not the mechanism of awareness itself. Some of the traditional definitions for the word "consciousness", including *the ability to consolidate memories*, *response to stimuli*, or the clinical concept of *impaired consciousness* may not be helpful. Consciousness, as we understand it here, operates with respect to individual qualia; sensory, cognitive, affective percepts, the sense of self, or the "mind" in which they exist. However, consciousness would still be present with only one percept, even with no "self" to interpret it, since we have posited that even a simple magnet will have a rudimentary consciousness, as will a bacterium with a single magnetosome (see fig.1). An impaired consciousness, unable to integrate its percepts, affects,

and cognitions, or to support the sense of self, would still retain the capacity for subjective experience. Consciousness would be in an 'on' state at all times, even if it's normal sensory, affective, and cognitive inputs were not.

Consciousness appears to be the environment in which states of consciousness exist and change while integrated experience and the sense of self are *state specific* phenomena. Tests that examine aspects of the sense of self cannot be expected to elucidate the phenomenon of consciousness. Studying trees may not answer specific questions about soil. Memory, for example, depends on states of consciousness insofar as not all *states* permit memory retrieval or consolidation equally. In addition, not all *states* can maintain the sense of self, which may not exist during dreamless sleep, even though brain imaging displays clear signs of neural activity in these states.

In our model, self-awareness is actually not a feature of consciousness, when viewed only as "the capacity for subjective awareness". Rather, it constitutes awareness of a specific, though subtle phenomenon; the *sense of self*.

Conclusion

The notion that consciousness is an intrinsic property of magnetic fields has a significant explanatory power, and does not rely on any non-consensual paradigms or metaphysical concepts.

Received September 30, 2019; Accepted October 12, 2019

References

[1] Kirschvink, Joseph L., Atsuko Kobayashi-Kirschvink, and Barbara J. Woodford. "Magnetite biomineralization in the human brain." *Proceedings of the National Academy of Sciences* 89.16 (1992): 7683-7687. https://www.pnas.org/content/89/16/7683

[2] Kirschvink, Joseph L., Atsuko Kobayashi-Kirschvink, Juan C. Diaz-Ricci, and Steven J. Kirschvink. "Magnetite in human tissues: a mechanism for the biological effects of weak ELF magnetic fields." *Bioelectromagnetics* 13, no. S1 (1992): 101-113. http://web.gps.caltech.edu/~jkirschvink/pdfs/KirschvinkBEMS92.pdf

[3] Bókkon, Istvan, and Vahid Salari. "Information storing by biomagnetites."*Journal of biological physics* 36.1 (2010): 109-120. https://www.researchgate.net/publication/26787386_Information_storing_by_biomagnetites

[4] Brenner, D., et al. "Somatically evoked magnetic fields of the human brain." *Science* 199.4324 (1978): 81-83. https://www.ncbi.nlm.nih.gov/pubmed/17569490

[5] Murphy, Todd "The production of consciousness out of states of consciousness" *Activitas Nervosa Superior*, Vol 51, No 3 (2009)
https://link.springer.com/content/pdf/10.1007%2FBF03379928.pdf

[6] Sperry, Roger (1980). "Mind-Brain Interaction: Mentalism, Yes; Dualism, No" *Neuroscience* Vol. 5, pp. 195 to 206, Pergamon Press Ltd 1980.
https://www.sciencedirect.com/science/article/abs/pii/0306452280900986

[7] Barber-Zucker, Shiran, Noa Keren-Khadmy, and Raz Zarivach. "From invagination to navigation: The story of magnetosome-associated proteins in magnetotactic bacteria." *Protein Science* 25, no. 2 (2016): 338-351.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4815348/

[8] Maestú, Ceferino, et al. "Reduction of pain thresholds in fibromyalgia after very low-intensity magnetic stimulation: A double-blinded, randomized placebo-controlled clinical trial." *Pain Research & Management: The Journal of the Canadian Pain Society* 18.6 (2013): e101.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3917800/

[9] Persinger, M.A., 1997. "Metaphors for the effects of weak, sequentially complex magnetic fields." *Perceptual and motor skills*, *85*(1), pp.204-206.
https://www.ncbi.nlm.nih.gov/pubmed/9293578

[10] Wang, Connie X., Isaac A. Hilburn, Daw-An Wu, Yuki Mizuhara, Christopher P. Cousté, Jacob NH Abrahams, Sam E. Bernstein, Ayumu Matani, Shinsuke Shimojo, and Joseph L. Kirschvink. "Transduction of the Geomagnetic Field as Evidenced from Alpha-band Activity in the Human Brain." *eneuro* 6, no. 2 (2019).
https://www.eneuro.org/content/6/2/ENEURO.0483-18.2019

[11] Persinger, Michael A., and K. Makarec. "Possible learned detection of exogenous brain frequency electromagnetic fields: a case study." *Perceptual and motor skills* 65.2 (1987): 444-446.
https://www.ncbi.nlm.nih.gov/pubmed/3696915

[12] Persinger, M. A. "Putative perception of rotating permanent magnetic fields following ingestion of LSD." *Perceptual and motor skills* 87.2 (1998): 601-602.
https://www.ncbi.nlm.nih.gov/pubmed/9842609

[13] Persinger, Michael A. "Out-of-body-like experiences are more probable in people with elevated complex partial epileptic-like signs during periods of enhanced geomagnetic activity: A nonlinear effect." *Perceptual and Motor Skills* 80.2 (1995): 563-569.
https://www.ncbi.nlm.nih.gov/pubmed/7675591

[14] Persinger, M. A., and S. A. Koren. "A theory of neurophysics and quantum neuroscience: implications for brain function and the limits of consciousness." *International Journal of Neuroscience* 117.2 (2007): 157-175. Appearing in: Nunez, Paul L. "Towards a physics of neocortex." *Advanced Methods of Physiological System Modeling*. Springer US, 1989. 241-259.
https://www.ncbi.nlm.nih.gov/pubmed/17365106

[15] Murphy, Todd. "The structure and function of near-death experiences: An Algorithmic reincarnation hypothesis." *Journal of Near-Death Studies* 20.2 (2001): 101-118. https://link.springer.com/article/10.1023/A:1013010306070

[16] Persinger, Michael A., and Linda S. St-Pierre. "The physical bases to consciousness: Implications of convergent quantifications." *J. Sys. Integrat. Neurosci* 1 (2015): 55-64. https://www.oatext.com/The-physical-bases-to-consciousness-Implications-of-convergent-quantifications.php

[17] Liboff, A. R. "The electromagnetic basis of social interactions."*Electromagnetic biology and medicine* 36.2 (2017): 177-181. https://www.ncbi.nlm.nih.gov/pubmed/27786565

[18] Kingsbury, L., Huang, S., Wang, J., Gu, K., Golshani, P., Wu, Y.E. and Hong, W., 2019. Correlated Neural Activity and Encoding of Behavior across Brains of Socially Interacting Animals. *Cell*. https://www.ncbi.nlm.nih.gov/pubmed/31230711

[19] Zhang, Wujie, and Michael M. Yartsev. "Correlated Neural Activity across the Brains of Socially Interacting Bats." *Cel l*(2019). https://www.ncbi.nlm.nih.gov/pubmed/31230710

[20] Leong, Victoria, Elizabeth Byrne, Kaili Clackson, Stanimira Georgieva, Sarah Lam, and Sam Wass. "Speaker gaze increases information coupling between infant and adult brains." *Proceedings of the National Academy of Sciences*114, no. 50 (2017): 13290-13295. https://www.pnas.org/content/114/50/13290

[21] Rao, Rajesh PN, Andrea Stocco, Matthew Bryan, Devapratim Sarma, Tiffany M. Youngquist, Joseph Wu, and Chantel S. Prat. "A direct brain-to-brain interface in humans." *PloS One* 9, no. 11 (2014): e111332 https://www.ncbi.nlm.nih.gov/pubmed/25372285

[22] Grau, Carles, Romuald Ginhoux, Alejandro Riera, Thanh Lam Nguyen, Hubert Chauvat, Michel Berg, Julià L. Amengual, Alvaro Pascual-Leone, and Giulio Ruffini. "Conscious brain-to-brain communication in humans using non-invasive technologies." *PLoS One* 9, no. 8 (2014): e105225. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4138179/

[23] Lesniak KT."The effect of intercessory prayer on wound healing in nonhuman primates." *Alternative Therapies in Health and Medicine*.2006 Nov-Dec;12(6):42-8. https://www.ncbi.nlm.nih.gov/pubmed/17131981

[24] Barker, Anthony T. "An introduction to the basic principles of magnetic nerve stimulation." *Journal of clinical neurophysiology: official publication of the American Electroencephalographic Society* 8, no. 1 (1991): 26-37. https://www.ncbi.nlm.nih.gov/pubmed/2019648

[25] Murphy, Todd. "*Sacred Pathways: The Brain's Role in Religious and Mystic Experiences*." Createspace Publishers, 2015.

[26] Feuillet L, Dufour H, Pelletier J. "Brain of a white-collar worker". *Lancet*. 2007 Jul 21;370(9583):262. https://www.thelancet.com/journals/lancet/article/PIIS0140673607611271/fulltext

[27] Gažová Z, Antošová A, Krištofiková Z, Bartoš A, Ríčný J, Cechová L, Klaschka J, Rípová D. "Attenuated antiaggregation effects of magnetite nanoparticles in cerebrospinal fluid of people with Alzheimer's disease." *Molecular BioSystems*. 2010 Nov;6(11):2200-5. https://www.ncbi.nlm.nih.gov/pubmed/20721410

[28] Yu F, Jiang QJ, Sun XY, Zhang RW. "A new case of complete primary cerebellar agenesis: clinical and imaging findings in a living patient". *Brain*. 2015 Jun;138(Pt 6):e353. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4614135/

[29] Glickstein M. "Cerebellar agenesis". *Brain* 1994;**117**(Pt 5):1209-12. https://www.ncbi.nlm.nih.gov/pubmed/7953600

[30] Boyd CA. "Cerebellar agenesis revisited". *Brain* 2010;**133**(Pt 3):941-4. https://www.ncbi.nlm.nih.gov/pubmed/19843649

[31] Klarica M, Orešković D (2014). "A new look at cerebrospinal fluid movement". *Fluids Barriers CNS*. 11. doi:10.1186/2045-8118-11-16. https://www.ncbi.nlm.nih.gov/pubmed/25089184

[32] Jang, S. H., and H. S. Kim. "Aneurysmal subarachnoid hemorrhage causes injury of the ascending reticular activating system: relation to consciousness." *American Journal of Neuroradiology* 36.4 (2015): 667-671. https://www.ncbi.nlm.nih.gov/pubmed/25572950

[33] Proctor, Lorne D., Robert S. Knighton, and John A. Churchhill. "Variations in consciousness produced by stimulating reticular formation of the monkey." *Neurology* (1957). https://psycnet.apa.org/record/1958-00097-001

[34] Koubeissi, Mohamad Z., et al. "Electrical stimulation of a small brain area reversibly disrupts consciousness." *Epilepsy & Behavior* 37 (2014): 32-35. https://www.ncbi.nlm.nih.gov/pubmed/24967698

[35] Koch, Christof, et al. "Neural correlates of consciousness: progress and problems." *Nature Reviews Neuroscience* 17.5 (2016): 307-321. https://www.ncbi.nlm.nih.gov/pubmed/27094080

[36] Thomson, Helen , "Consciousness on-off switch discovered deep in brain" *New Scientist* 2 July 2014 https://www.newscientist.com/article/mg22329762-700-consciousness-on-off-switch-discovered-deep-in-brain/