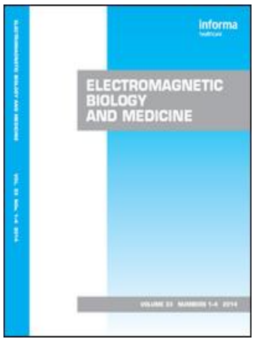

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ORIGINAL ARTICLE

Magnetic correlates in electromagnetic consciousness

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ABSTRACT
We examine the hypothesis that consciousness is a manifestation of the electromagnetic field, finding supportive factors not previously considered. It is not likely that traditional electrophysiological signaling modes can be readily transmitted throughout the brain to properly enable this field because of electric field screening arising from the ubiquitous distribution of high dielectric lipid membranes, a problem that vanishes for low-frequency magnetic fields. Many reports over the last few decades have provided evidence that living tissue is robustly sensitive to ultrasmall (1–100 nT) ELF magnetic fields overlapping the γ-frequency range often associated with awareness. An example taken from animal behavior (coherent bird flocking) lends support to the possibility of a disembodied electromagnetic consciousness. In contrast to quantum consciousness hypotheses, the present approach is open to experimental trial.

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Introduction

The great advantage in any field approach to the problem of consciousness is its unifying character, allowing one to regard consciousness in a global manner (Pockett, 2013). More specifically, recent arguments suggested (Pockett, 2000, 2012, 2013; McFadden, 2001, 2002, 2007, 2013) that the electromagnetic (EM) field may play a unifying role in brain function, facilitating the binding of multimodal sensory data viewed as integral to conscious experience. Pockett (2000), focusing on the extensive appearance of seemingly independent oscillatory neural processes, proposed the provocative hypothesis that "Consciousness is identical with certain spatiotemporal patterns in the electromagnetic field." There is no question that incorporating EM field-mediated communication into models of brain function has the potential to reframe discussions surrounding consciousness. However, to the best of our knowledge, all previous discussions concerning this possibility only focused on traditional electrophysiological parameters, with no recognition of the role likely played by the magnetic field.

Electromagnetic fields generated within localized brain structures can exert effects more globally within the brain and may therefore transcend purely connectionist models of brain function. Related phenomena involving interactions generated from multiple sources, particularly those involving the frequency, phase and coherence of oscillatory fields, suggest a more unitary view of brain function often regarded as an important requirement for consciousness. Such field-mediated communication within the brain suggests that the laws of physics pertaining to electricity and magnetism and signal processing may be more applicable in this context then had previously been supposed.

In considering the nature of such EM field-mediated communication within the brain, one must recognize that there are severe physical constraints involved. The voltages and currents generated during neural excitations are extraordinarily weak, so that important questions arise as to limits on detectability. In partial response to this question of signal threshold, McFadden (2001, 2002) pointed out that the case for an electromagnetic contribution to brain function and consciousness is strengthened considerably when one considers increases in field intensity resulting from synchronicity, that is, many neurons acting in concert. However, no evidence is provided to indicate how such synchronicity is enabled.

In the following section, we explore general questions related to EM field-mediated communication within the brain and its relationship to consciousness and investigate field levels possible given the physical characteristics of the nervous system. We broaden the focus that limits consideration to traditional electrochemical strategies, widening the possibility to include ultraweak magnetic fields derived from axonal and postsynaptic charge flows. A more comprehensive literature-based provenance of experimental studies is

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provided detailing electromagnetic effects on the brain. Finally, we point one interesting potential consequence of using a field concept to describe consciousness, applying a gedanken model to cooperative animal behavior to illustrate a primitive electromagnetic neural scenario.

Characterizing the electromagnetic field

The electromagnetic (EM) field, similar to the other three fields in nature (gravitational, strong, and weak) is defined in terms of the force it exerts. Thus, the intensity of the EM field at any point in space is measured by the force that it exerts on electric charges and magnetic dipoles. Because of its vector nature, its direction must be specified at each point. A field can be static, that is, unchanging in time, or time varying. It can be uniform such that within a given region, it is the same in intensity and direction, or it can vary from point to point. These differences are determined by the sources of the field, the electric charges or the magnetic dipoles or both. When we attempt to relate the electromagnetic field to the brain and specifically to its possible role in consciousness, we can anticipate that any such field must be derived from both electric and magnetic sources, that it will be quite non-uniform, and that it must necessarily vary in time.

In its most literal sense, there is only one EM field, one that fills all of space. This does not mean that electromagnetic consciousness, if it truly exists, implies some sort of connecting link between all conscious creatures. The presumption of information transfer underlies EM consciousness, and although the EM field extends to great distances, its ability to convey information falls off rapidly with distance due to decreasing signal-to-noise ratios.

The precise mathematical understanding of the EM field dates back to its formulation by James Clerk Maxwell in the latter half of the nineteenth century. Perhaps the most important thing about Maxwell's equations is the way that they reveal the interconnectedness of the electric and magnetic vector components that comprise the EM field. These components are often labeled E and B, respectively, for electric field and magnetic field. The electric field strength in the brain is mostly manifested by the voltage differences across cell membranes. The magnetic field is determined by currents, derived from the passage of charge along axons and associated neural tissues. This distinction between electric and magnetic sources is mirrored when discussing action potentials as opposed to current dipoles. A similar dichotomy occurs when comparing electroencephalography to magnetoencephalography (EEG to MEG), as something solely dependent on E and something solely dependent on B. In making this distinction, the reader is cautioned against thinking that these two measures of the electromagnetic field are merely two sides of the same coin. The electric properties of the brain are quite different from the magnetic.

To properly describe the electromagnetic field in any substance, it is necessary to know the electrical and magnetic properties of that substance. The two key parameters used to characterize different substances, including brain tissues, are the electric permittivity ε and magnetic permeability μ. With very few exceptions, the permeability of all living tissues, including that of the brain, is hardly different from free space. This means that neural tissues are transparent to magnetic fields. On the other hand, the permittivity ε varies considerably from point to point in the brain, mostly reflecting the large differences in conductivity among lipid membranes, axonal fluids, and neurotransmitters.

This fact makes it difficult to conceive a mechanism by which information, in the form of electric field changes, could be successfully transported from within an individual cell body to remote areas in the brain. The difficulty lies with the cell membrane, whose E field is so large that it considerably reduces the external transfer of electric field changes generated within the axon or dendrite, an effect that can be thought of as membrane shielding. Indeed, it is generally recognized that one of the important functions served by lipid membranes is to protect the cell interior from unwanted external electric field effects. In other words this same membrane shield prevents electric signals within the cell from being easily transmitted. Instead ion pumps and channels are used to provide transmembrane information flow.

This problem is not shared with magnetic fields. The magnetic field generated by a current-carrying axon is in principle capable of being detected throughout the cranium, the only limitation being the size of the current. This distinction does not mean that any electromagnetic field representing consciousness is necessarily independent of the local electric field. The E field within neural tissue is probably not responsible for information transfer over large regions of the brain but is likely involved in EEG and similar volume conduction effects. Even though a complete description of the EM field is dependent on knowing both E and B, there are situations where the EM field is adequately described simply either as an E field or as a B field. For example, the EM field in a region where there are no moving charges is purely an electric field. Conversely, B fields occur where one is only concerned with the presence of magnetic dipoles or effects due to moving charges, with the local electric field either unimportant or very small. This is particularly important within the range of the extremely low frequencies (ELF) that might be associated with consciousness, that is, below a few 100 Hz. Indeed, there is good reason to believe that weak ELF magnetic field effects may be an essential component of the connection between the EM field and consciousness.

The electromagnetic origin of mind

Quite apart from limiting consideration solely to the brain, the nature of biological expression itself may be essentially EM, something previously theorized by the author (Liboff, 1994, 2004, 2005). If this is the case, then it is reasonable to think that the brain, as one part of the entire organism, should also reflect this property.

In this scenario, life is regarded as a consequence of the EM field of force, one of the four force fields that physics uses to describe reality. The living state, in this view, falls naturally into the increasingly complex sequence of EM configurations that nature has constructed beginning first with the simple delineation of electric charge in electrons, through successively higher-level systems of atoms, then molecules, polymers, and finally into the present EM configuration that we describe as the living state. In this context, just as the appearance of atoms and molecules in nature is hardly mysterious, this is no less true for life.

This categorization of living things as an expression of the EM field still manages to reflect the usual cast of biological/biochemical observables that are found genetically, somatically, and instantaneously. In this view all the detailed biochemical parameters that comprise the entire organism-the component enzymes, lipids, deoxyribo nucleic acid/ribo nucleic acid (DNA/RNA) states, sugars, etc, – are regarded as contributing to an equivalent electromagnetic polarization vector that varies in time as the organism changes. The biochemical details are maintained exactly as described in present-day textbooks, but their effects are replaced by the global field that results from the overall instantaneous configuration of charges and currents. Using this approach, one level of reductionist detail is removed and an overarching generalization is revealed. The EM field viewed in detail is no less complex than the components it replaces, but as a whole it represents a unifying synthesis, dependent only on electromagnetic parameters such as E, B, ε, and μ.

Given this approach to synthesizing the biological components of the entire living thing, one cannot reasonably exclude the brain, as part of the whole, from also being described in similar fashion. One can therefore perhaps regard consciousness as merely one more example of electromagnetic biology, something uniquely specific to the brain. In this view, associating the EM field with brain function does not mean that this field is anything more than a convenient description, merely corresponding to what is observed elsewhere in the overall biological system. Nonetheless, the interesting question remains: If the field description of living things is an accurate measure of the living state does this imply that it also carries the role of biological expression, that the living state unfolds in time as dictated by the EM field? This has the effect of evolution "capturing" the EM field in the same way as other physical realities are utilized, absorbed into the genome for purposes of survival. If one adopts this point of view, then it can also be argued that consciousness is an expression of the electromagnetic field. Just as the body's EM field helps maintain liver function and homeostasis, it also serves to realize brain function.

In any event, regardless of how electromagnetic consciousness came about, whether as part of something larger, or as a unique addition, the outcome had enormous evolutionary significance, enabling the nervous system to not only react to stimuli, but also to control them. We imagine evolution as recognizing the EM field as a powerful adaptation for the nervous system, providing higher-level animals and particularly humans with a unique survival strategy.

Weak extremely low-frequency (ELF) magnetic interactions

The neurophysiological community has failed to take note of the abundant peer-reviewed literature reporting that weak ELF magnetic fields interact with living things. Many of these reports indicate that this type of interaction is observed at remarkably small intensities, a fact that has relevance to the general question of EM consciousness. One cannot simply ignore this literature base, as when McFadden (2002) wrote "*The issue of the sensitivity to weaker [fields] is entangled with the power line controversy, which despite many studies, remains contradictory and unresolved.*" It may be true that the power line controversy, primarily epidemiological in nature, remains unresolved, but a host of well-replicated independent laboratory studies (Fitzsimmons et al, 1995; Goodman and Henderson, 1988; Liboff, 1984, 2006; Walleczek and Liburdy, 1990) reveal that the interaction capabilities of weak magnetic fields with living tissues are reasonably certain.

By far the most significant of these was the work by Zhadin et al (1998) reporting that AC magnetic fields as weak as 40 nT can significantly affect the conductivity of glutamic acid in aqueous suspension, an observation not only consistent with earlier animal studies (Beason, 2005; Martin and Lindauer, 1977; Walker and Bitterman, 1989) but later replicated elsewhere independently (Alberto et al, 2008; Comisso et al, 2006; Pazur, 2004). This result involving vanishingly small magnetic intensity opens the door to serious consideration that magnetic fields may play a heretofore unsuspected role in brain function. Even earlier, considerable evidence had accumulated showing that neural systems are sensitive to weak magnetic fields, particularly in studies on rat behavior (Lovely et al, 1993; Lyskov et al, 1996; Thomas et al, 1986; Zhadin et al, 1999). The primary conclusion of these studies was that activation of the *N*-methyl*D*-aspartate (NMDA) glutamate receptor, deeply involved in synaptic plasticity, memory, and learning, is affected by weak ELF magnetic fields (Frilot et al, 2014; Manikonda et al, 2007). In this connection, Flohr (2000) argues that the plasticity of NMDA receptors is a necessary condition for consciousness.

Further, work on anesthetized rat hippocampus has shown that electrical activity among pyramidal neurons is affected by weak ELF magnetic fields (Jenrow et al, 1998). These magnetically induced changes persisted for 10s of minutes after removal of the field, lending strength to the likelihood that such fields affect synaptic plasticity. The investigators in this work also hypothesized the existence of endogenous magnetic fields "mediating" neuronal synchrony. To add to this picture, other studies reported that the EEG output in rats and in human is significantly affected by ELF-weak magnetic fields, applied either as pure sinusoidal waves or as modulations of higher radiofrequency signals (Marino et al, 2004; Takashima, 1979; Vorobyov et al, 1997, 1998, 2010). Finally, in studies that may have no bearing on consciousness *per se*, but nevertheless lend strength to the remarkable sensitivity of neural tissue to magnetic fields, various investigators found that proliferation in neuroblastoma cell culture is also affected by weak ELF magnetic fields (Blackman et al, 1994; Horton et al, 1993; Smith et al, 1992).

This large body of literature impacts the question of EM consciousness. If, as so thoroughly demonstrated in these reports, externally applied weak magnetic fields are interactive with neural tissue, then the endogenous equivalent of such fields must also be considered as possible factors involved in consciousness.

Synchronicity

The question of synchronicity arises when trying to demystify binding, that aspect of consciousness whereby long-range seemingly simultaneous recruitment of multiple sensory inputs occurs, enabling one to experience the unified sense of being (Jefferys et al, 1996; Tomoni and Edelman, 1998). No satisfactory explanation has yet been agreed. Synchronicity can be approached in various ways, not the least of which is Adey's vision of cells "whispering together." There is the potential for enhanced information transfer when action potentials fire simultaneously, either among parallel arrays of axonal fibers or by means of some remote coupling processes. Presumably, this type of synchronicity is subject to traditional electrophysiological constraints, including the relatively long times associated with biochemical signal creation at cell membranes. A single axonal voltage change can be used to advantage by the many postsynaptic connections, leading to large-scale dissemination of information throughout the brain. However, it is important to note that the coupling mechanism, whereby multitudes of like processes occur synchronously, remains obscure.

Another type of postulated synchronicity is long-range resonance recognition, where remote areas of the brain appear to be sensitive to specific frequencies referred to as gamma waves, often occurring in the 25–100 Hz range. Considerable weight is attached to the observation that gamma waves disappear under anesthesia, tending to reinforce the notion that they are a measure of awareness. We find good reason to think that endogenously generated magnetic fields are directly related to the phenomenon of synchronicity.

This range of gamma wave frequencies is remarkably close to the frequency range that is found in the various ELF studies mentioned previously. Of particular interest are those interactions occurring at ion cyclotron resonance (ICR) frequencies (Liboff, 2006). Not only do gamma wave frequencies correspond closely to these ELF interactive frequencies, but the overall timing is greatly reduced when comparing magnetic field changes to electrophysiological processes. Most critically, the well-described resonance capabilities of living things to specific magnetic frequencies (Baureus-Koch et al, 2003; Fitzsimmons et al, 1995; Foletti et al, 2013; Gaetani et al, 2009; Liboff, 1985; Zhadin et al, 1998, 1999; Vorobyev et al, 1998) provides a reasonable basis on which to begin to explain large-scale synchronicity.

Also, because of membrane "shielding," we specifically rule out any global effects due to long-range cooperative electric field changes. It has already been pointed out that the neural environment includes a wide variety of electrical conductivities, making it difficult to retain or distribute coherent systematic changes in electric field. Indeed, as mentioned earlier, it has often been observed that one important function of the cell membrane is to shield the interior against unwanted external electrical perturbations. This natural barrier to electric communication does not similarly apply to remote magnetic signals generated by axonal currents. Thus, although the view of an EM spatiotemporal structure to express consciousness has great merit, it is unlikely that the electric field vector E alone is capable of providing a suitable means of information transfer through synchronicity. On the other hand, any magnetic field component, generated locally, has wide access to the entire brain, particularly at low frequencies. In short that part of the brain's EM field related to binding is due to oscillatory magnetic fields that are derived from local electric currents. In this way, complex information transfer may be enabled throughout the brain.

It is interesting that neuroscientists do not ordinarily view the information transfer that occurs during neural excitation in terms of electric current. In part, this is because ionic displacement is involved, as opposed to electron flow. Further, the most readily available experimental variable is the voltage change at the scalp, as measured in EEG. Even the classic squid axon preparation routinely categorizes propagation signals in terms of voltage. One refers to evoked potential, rarely to evoked current. But the fact remains. Potential differences may be easier to measure, but the critical event necessarily involves charge transfer. The most elementary neurophysiological event is always the result of a change in net charge δq, occurring over the time δt, giving rise to a current $i = \delta q/\delta t$, and therefore by virtue of the Biot–Savart Law, an associated magnetic field. The complex of such individual mini-fields in a single brain can be summed over their intensities and relative directions to result in an uberfeld that is both unique to the individual and a physical realization of his/her consciousness.

It is useful to estimate the level of current required to produce a detectable magnetic field. Reliable reports (Zhadin et al, 1998) discovered that fields as small as 10–100 nT and, in one case, between 1 and 10 nT (D' Emilio et al, 2014) can be detected in biological and biochemical systems. Accordingly, we will assume that in order for a magnetic field to be found useful in the nervous system, its intensity must be on the order of 1–100 nT. However, in order to achieve a basis for electromagnetic consciousness, not only is it required that neural elements are capable of detecting the consequent magnetic information, but such elements must also be capable of generating this information. It is therefore critical to determine the maximum possible magnetic intensity generated by current elements, presumably of axonal and dendritic origin. It is tempting to believe that fields of 1–100 nT are endogenously generated in the brain, something that would provide a strong likelihood for synchrony and binding. In this connection, we note that this range of magnetic intensity has yet to be explored. Magnetoencephalography (MEG) has specifically focused on much smaller field intensities, ranging from 10s of fT (10^{-15} T) to 1000s, weaker by a fraction of about ten thousand than our projected values. However, MEG devices are specifically designed to prevent the measurement of unwanted larger biomagnetic signals, certainly those in the 1–100 nT region.

At much larger magnetic field intensities, the lack of any perceived neurological effects resulting from Magnetic resonance imaging (MRI) has also led some to discount the possibility of EM consciousness. However, one distinguishing feature of the observed responses to ELF magnetic fields has been the fact that these responses are not found at higher intensities, but limited to certain weak intensity windows (Bawin et al, 1976; Blackman et al, 1989; Lednev, 1991), in all cases many orders of magnitude less than MRI intensities. Indeed, recent studies indicate that these intensities are so small as to warrant the use of hypomagnetic research facilities (Alberto et al, 2008, Comisso et al, 2006; D' Emilio et al, 2014; Pazur, 2004;), without which, as first observed by Zhadin (1998), the effects of these vanishingly small fields are not detectable.

Can consciousness be shared?

We have already mentioned that the transfer of useful electromagnetic information falls off rapidly with distance from the source of the field. However, it must be noted that this falloff can be finessed to some extent by signal processing. Very narrow frequency bandwidths can in some cases be detected in the presence of noise, providing that source and receiver are properly matched in frequency response. If indeed EM consciousness is a reality, involving very weak magnetic fields, this could have interesting consequences. For example, some fraction of one's mental field might be available to others nearby. We can offer no evidence in support of this possibility. Nonetheless, considering the profound nature of what is involved, it is worth examining the potential effects on human interactions.

In approaching this question, we focus on a longstanding problem in animal behavior, the remarkable cooperative interaction found during bird flocking (Cavagna et al, 2010; Hemelrijk and Hildenbrandt, 2011), a phenomenon that can involve tens of thousands of birds at a time, and often extends over the greater fraction of a kilometer. One puzzling mystery is that the correlation between birds does not decay with distance (Cavagna et al, 2010), making it difficult to believe that information can be conveyed as cues from bird to bird to enable what appears to be a unitary response.

We raise the possibility that neuroelectromagnetic signals originating in a bird's brain may serve as a means of nearly instantaneous, speed of light, information transfer among all the birds. Instead of bird-to-bird sensing of visual cues an EM field is, in effect, shared by the entire flock.

We can attempt to flesh out such behavior in terms of this commonly sensed EM field. Consider a large flock of birds, each of which is equally capable of both generating a local field as well as responding to such a field. Assume that all the individuals comprising this flock can equally transmit and receive the same neural information, conveniently labeled as $f_i(B)$, where the index *i* specifies the individual bird and where the functional dependence is on the local magnetic field *B*. We can therefore state that $f_i(B) = f_{i+1}(B)$ for each and every member of the group. A little thought will reveal that this function can also be replaced by a single representation for the entire group. If we arbitrarily associate $f_i(B)$ with the movement of the *i*th bird, this connection to movement must also apply to all the birds in this flock. Each bird contributes to the whole, but for a large flock adding or subtracting one or even a few birds does not affect the bulk activity of the larger entity comprising the flock. Also, more than merely the magnetic intensity alone would be needed to provide bird-to-bird signaling. Without knowing precisely how the function $f(B)$ is constructed, it seems clear that it must reflect a *change* in *B*, rather than *B* itself.

In one sense, this provides a *de facto* explanation, however speculative, of all cooperative motional phenomena such as bird flocking and fish shoaling. But a separate conclusion can also be drawn. Simply stated this cooperative neural behavior arising from the summation of the many individuals in the flock is indistinguishable from that of a single imagined system exhibiting an equivalent unitary behavior. Indeed, Couzin (2007) deliberately used the phrase "collective mind" to describe this behavior. We add to this view, suggesting that the contribution of the individual bird vanishes and is replaced by a unique "nervous system," common to all. In effect, we idealize the neural characteristics of the entire group in terms of a single entity that represents the whole. This entity, although determined from the neural activity of individual birds, is nonetheless independent of individual birds.

This entity amounts to an electromagnetic distillate of neural function, illustrating in a very basic way how an electromagnetic field can be thought of as something that describes brain activity but is still independent of its individual elements. We make the leap to electromagnetic consciousness, arguing that it too can be regarded as a stand-alone physical entity.

Discussion

Various speculations have been advanced (Baars and Edelman, 2012; Hameroff, 1994, 2012;Hameroff and Penrose, 2014; Penrose, 1989, 1994) that consciousness has its basis in emergent physics, specifically the remarkable observations (Aspect et al., 1982) which upset our notions about particle locality, summarized in the phrase quantum entanglement. Well-accepted features of reality in physics, such as nonlocality and an energy-filled vacuum, are also potentially attractive concepts for use in consciousness. In some respects, this approach to consciousness is an extension of the older Copenhagen school of quantum mechanics, originating with Bohr and Heisenberg, which regarded mind as an ingredient of reality, realized when an individual makes a choice that collapses one wave function to the exclusion of all others. In another respect, the involvement of quantum theory can be seen as conflating computation with consciousness, the argument boiling down to saying that thinking is similar to large-scale parallel computing. In any event, it has proven difficult to conceive of an experiment to test this idea. Perhaps the most telling criticism of the quantum approach to consciousness came from Chalmers, who proposed *"… a Law of Minimization of Mystery: consciousness is mysterious and quantum mechanics is mysterious, so maybe the two mysteries have a common source"* (Chalmers, 1995).

We have shown that physics can play a central role in the problem of consciousness, quite independently of the approach associated with quantum modeling. In particular, there is good reason to support a modified version of the Pockett hypothesis that consciousness is a consequence of the electromagnetic field. Specifically, we argue that endogenous low-frequency magnetic signals derived from axonal and neurotransmitter charge flow must also be considered in addition to the more readily recognized electric parameters. Our argument is strengthened by the many reports over the past few years showing that neural expression is surprisingly responsive to weak magnetic fields, particularly in the 25–100 Hz frequency range implicated by many with the question of binding, lending one to believe that such fields are similarly generated in the brain.

Without the presence of such fields, it is not clear that a reasonable EM hypothesis is possible. There is no obvious means of large-scale, electrophysiological information transfer from axonal sources to remote areas in the brain. This is because the ubiquity of lipid membrane structures in the brain ensures that axonal voltage changes are not directly shared externally. Lacking a magnetic means of communication the global delivery required for unitary consciousness instead reverts to the present biochemical paradigm, which is, by definition, completely different from a field model.

We envision EM consciousness as necessarily requiring the capability of rapid intrabrain information transfer. In order to properly utilize the EM field, this requirement carries important physical constraints. Thus, EM consciousness is dependent on both the level of sensitivity to very weak fields within neural tissues and the corresponding capability to also generate detectable currents. Our present knowledge indicates an approximate sensitivity of 1–100 nT within biological tissues, suggesting that there is good reason to search for endogenously generated magnetic signals in this range. Unlike quantum explanations of consciousness, an EM hypothesis involving these field intensities can be experimentally explored.

Such magnetic signals at these intensities are generated by the brain implies something not possible with the present neuroelectric paradigm, namely that signals originating within the brain may be detected externally by others, suitably attenuated. Thus, if consciousness is an expression of the EM field, then one possible consequence may be near-field interbrain communication. This should not be construed as akin to extrasensory perception, but rather as a previously undescribed type of neurological effect perhaps best imagined as mind sharing. It is unlikely that the individually detailed complex gestalt that constitutes one's consciousness field can be successfully transmitted in coherent form to external systems. Rather we are suggesting that limited fractions of an individual's EM field are sufficiently strong to bridge the neurological activity in nearby sentient systems, possibly appearing as unrecognized magnetic cues. This distinction between subtle cues and full-blown thoughts can be taken to mean that even if consciousness *per se* cannot be electromagnetically shared, there may still be weakly interactive influences. We may be immersed in such magnetic cues without being aware of it.

An interesting speculation follows from the two sharply contrasting neural approaches, one the presently accepted biochemical/electrophysiological paradigm, the other involving the electromagnetic field. The former body of knowledge is very widely accepted, with every reason to believe it still plays an important role in neurophysiology. One can perhaps suggest that this well-accepted biochemical basis to consciousness may be vestigial, a carry-over from early neural applications in primitive creatures and that the neurological utilization of the electromagnetic field is a more recent evolutionary strategy, one through which mind first appeared. If this is the case, then there may be a bimodal quality to brain function, both biochemical and field-like, with greater use of the latter by higher-level animals, particularly humans.

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Declaration of interest

The author reports no conflicts of interest. The author alone is responsible for the content and writing of this article.

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