Exploring Our Physical Connections: The Role of Magnetic Fields in Restorative Environments

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Abstract
Despite the often heard mantra that "humans are nature too," the language found in ecopsychology literature is often that of disconnection, separation, and difference. While acknowledging that the complexities of human psychology often means that we perceive such a disconnection, this article argues that we are inseparably embedded within the physical environment. How this affects us physiologically and psychologically is illustrated by focusing on a specific example: the effects of the magnetic field environment on human psychology and physiology. How such effects might in general play a role in processes of attention restoration and place attachment are discussed with the hope that an increased awareness of physical factors and our embedded nature might generate novel insights for ecologically minded psychologists and therapists.

Introduction
Ecopsychology may be defined as the study of the interrelationships between the natural world and human mental processes, differing from environmental psychology in its aim to bridge the "long-standing, historical gulf between the psychological and the ecological" (Roszak, 1992). Yet, despite the often heard mantra that "humans are nature too," the language found in ecopsychology literature is often that of disconnection, separation, and difference. While it is certainly true that much of scientific (and, in many cases, religious) thought has historically attempted to place humans outside—or, more typically, above—the rest of the natural world (see, for example, Abram, 1997, pp. 47–48) this does not mean that such separation exists, or is even possible, outside of those human-made models.

Like every other living creature on Earth, humans evolved in a natural environment. Our senses are composed of cells which adapted to pick up some of the physical stimuli that exist on our planet and convert those stimuli to electrochemical signals that our brains can interpret: eyes that detect a specific range of wavelengths of the electromagnetic radiation we call "light"; ears that respond to a set range of physical vibrations in air; cells in the tongue and nose that react when certain chemicals are present; cells in our skin and organs which respond to a variety of stimuli including heat, pressure, movement and spatial orientation, or the presence of certain chemical substances. Even in the absence of specially adapted receptor cells, there are still other physical stimuli that can affect the way our bodies function. For example, research in the area of bioelectromagnetics shows us we can indirectly respond to electric and magnetic fields, whether these are generated artificially from mobile phones and electricity pylons (Cook, Saucier, Thomas, & Prato, 2006) or occur naturally due to the atmospheric movements we call "weather" (Persinger, 1980).

We therefore might expect that much of our thought processes and behaviors are also adapted to respond to such environments. As Gary Snyder says, "our bodies are wild" (Snyder, 1990, p. 16), so much so that a large proportion of modern day stress comes from us being not yet adapted to modern day lifestyles, especially in an urban setting. Many of us spend extended periods of time in the "fight or flight" state that evolved to be a transient, quick response to dangerous event (DeLongis, Folkman, & Lazarus, 1988). Working to job deadlines, studying for exams, crossing busy roads, trying to get somewhere on time using congested traffic systems—all of these situations induce floods of neurochemicals and hormones into our bodies, energizing muscle

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systems, suspending digestive processes, and generally increasing our arousal levels in an evolutionary regression to a more immediately life-threatening existence (Tsigosa & Chrousos, 2002). Even if we were never to be exposed to a natural setting, never gave a thought to the ecosystems we are part of or to the state of the global environment, our bodies are still remembering their evolutionary history, still connecting to the common origins of the species of animal we call "human."

This way of thinking is supported by empirical research into *restorative environments*—the idea that being in, or even just viewing an image of, certain natural(istic) environments is inherently relaxing and effortlessly engaging (Kaplan, 1995; Ulrich et al., 1991). Some researchers have suggested that this occurs due to our recognition on some innate level of scenes which have features corresponding to our "evolutionary home." For example, Balling and Falk (1982) found that children tended to express a preference for visual scenes of savannah but that this preference was lacking from older participants, who presumably had learned to disregard their innate responses.

That is not to say that we will always be aware of such connections. Our psychological perception of the world has many layers of complexity, combining physiological and mental processes in a truly interactive way. We have desires and beliefs that influence our attention, we forget some things and selectively remember others. In a real sense, we create the world we perceive, our expectations and memories combining with the incoming sensations to produce a model of the world inside our minds. That world thus contains a framework of what is "really out there" filled in with the sum total of who and what we are. As Varela, Thompson, and Rosch (1991) put it, ". . . organism and environment are mutually enfolded in multiple ways, and so what constitutes the world of a given organism is enacted by that organisms' history of structural coupling." That is to say, the world for any of us is unique, defined by the nature of the environment coupled with our personal and evolutionary history.

This complex idea is brought together in the seemingly simple term *embodiment*, the notion that our thoughts and experiences are intimately related to ". . . the kinds of bodies we have, the kinds of environments we inhabit" (Johnson, 1987). However, despite widespread use of the term, the emphasis has been on the body rather than the environment, with the notion of physical connections between the two even less represented in the literature. I think that we need to bring attention to the wider aspects of embodiment and think about our *embedment*[1] within the environment of which those bodies are an integral part. Even outside ecopsychology, there is much to support the idea that we are fundamentally connected to the world in which we are embedded, supporting the idea that these connections are not ones which can ever be truly broken.

Embedment in the Physical Environment

Consider the human body. We are a complex collection of interacting chemical and electrical processes. Every thought we have is associated with thousands, if not millions, of moving electrical charges. Every move we make involves more electrical charges moving along nerves as well as heat-generating mechanical movements of muscles. Basic physics tells us that those moving charges generate electric and magnetic fields that can extend far beyond the skin-defined boundary of our bodies. Theoretically, such fields extend to infinity; practically, some can still be easily detected at least a few meters away. Although subject to much debate, there is a growing body of literature demonstrating how such fields affect other organisms around us (e.g., Edmonds, 2001; Ho, Popp, & Warnke, 1994), as well as making us in turn sensitive to changes in the electric and magnetic field environment that surrounds us (e.g., Cook et al., 2006).

All the body heat we give off also affects our environment, whether this manifests as the thermal-imaging camera's map of where we have walked, or the way that cats and other animals (including partners, friends, and tired small children) want to snuggle up to us on a cold night. Every move we make sends sonic, subsonic, and ultrasonic vibrations through the air and ground: our footsteps are sensed by earthworms and other ground-dwelling creatures; our smaller movements are audible to bats, cats, and dogs. Everywhere we go, we leave behind a trails of chemicals—skin flakes, hairs, sweat, pheromones—that tell the world around us of the state we were in when we left them. At any given time, we are broadcasting our presence, our actions, our behaviors into the environment through an intricate web of physical connections.

And it works the other way round too: all we know of the world comes to us though a variety of physical interactions. We absorb chemicals in the form of tastes and smells. Our sense of hearing is based on the vibrations of the air around our bodies. We see when light—be it from the sun or other source—is reflected off or refracted through things around us and that light energy is then absorbed by the cells in our eyes. Even when we touch, the sensations we feel are the result of a very intimate connection with the touched surface. In a very real sense, we become a part of what we touch, the molecules of our skin momentarily becoming part of the molecular structure of that which we touch. Abram (1997, p. 68) put it well when he wrote, "We can experience things—can touch, hear and taste things—only because, as bodies, we are ourselves included in the sensible field, and have our own textures, sounds and tastes. We can perceive things at all only because we are entirely a part of the sensible world." To think of ourselves as self-contained, unconnected physical entities is far from a realistic model.

To illustrate this point, we can look at one specific example that has been the focus of many empirical studies: the ways in which humans respond both physiologically and psychologically to the strength and dynamics of magnetic fields in the immediate environment.

Responding to the Magnetic Environment

A magnetic field is the region around a magnet, electrical current, or changing electric field in which any electrically charged object (which includes most dynamic parts in biological systems) will feel a force—most people will remember this from textbook diagrams showing "lines of force" between the North and South poles of a magnet. In recent years, there has been a lot of interest in the effects of magnetic fields on human health and behavior, primarily due to the concerns about potentially negative effects of mobile phones. With the more recent publication of a large-scale case-control study (Hepworth et al., 2006), it now appears that the fear that normal usage was associated with increased risk of cancerous brain tumors was unfounded, and the general impression given by some researchers and the media is that the whole area is of little further interest. Unfortunately, this runs the risk of many researchers remaining unaware of a large body of literature into more general effects of magnetic fields (not necessarily negative) on human and other animal behavior. From the perspective of ecopsychology, this is especially unfortunate as the field of bioelectromagnetics has a lot to offer, both in terms of direct effects of site-specific magnetic environments and in offering useful insights into the effects of other physical factors in the environment.

Bioelectromagnetics is concerned with any interactions between biological systems and electromagnetic fields, range from static magnetic fields all the way up to the frequencies of visible light (electromagnetic radiation of which we are the most aware in everyday life). One key area looks at weak magnetic fields (less than 500 μT)[2] at biologically relevant frequencies (i.e., frequencies which correspond to the rhythms of various physiological processes in the human or other animal body, typically less than 100 Hz, where 1 Hz = 1 cycle per second). Such fields are present in all but the most-shielded environments, originating from a variety of sources, both natural and artificial. The most widespread natural component is the magnetic field that surrounds (and penetrates) the earth, thought to be generated by motion in the conducting fluid interior of the Earth and then subsequently modified through dynamic processes (solar ionization of the outer atmosphere, daily expansion and contraction of the upper atmosphere due to solar heating, and physical movement of the atmosphere due to tidal effects from both the moon and the sun). There are also more localized variation due to the presence of magnetic minerals in the earth's crust. The static component of the earth's magnetic field has strengths of around 40 μT, whereas the varying components due to the aforementioned dynamic processes are much weaker at less than 1 μT. There are also artificially generated magnetic fields which originate from any device having an electric current. The most prevalent fields are generated by electrical power lines and wiring, but significant sources also include electric trains, household appliances and lighting, and mobile phones. Artificial field strengths can vary from 0.5 μT to around 2,000 μT depending on the specific electrical wiring or appliance and the distance from the person.

It is still unclear why humans are affected by such fields. Unlike some other species, we do not appear to have any form of magnetic-sensing organ (Edmonds, 2001), and the current best model is that the fields directly affect the functioning of biological cell membranes (for those interested, the suggested mechanism is *ion resonance*. For examples, see Eichwald & Kaiser, 1993; Liboff, 1997). Some theorists have suggested that our responsiveness is the result of an evolutionary history embedded within a geomagnetic field that helped to shape our physiological systems (Cherry, 2003; Smith & Best, 1989) and it is certainly true that the circadian melatonin rhythm in mammals, generally described as being driven by the daily dark–light cycle, is strongly affected by magnetic fields in the absence of changing light levels (e.g., Reiter & Yaga, 1993). This particular effect is thought to involve the pineal gland, an organ which shares evolutionary ancestry with the mammalian eye (Mano & Fukada, 2007), suggesting that magnetic field responsiveness pre-dated visual sensing in the evolution of many species and strengthening the idea that our evolution has been affected by our immersion in the earth's natural magnetic field.

Whatever the reason for our susceptibility, it is increasingly clear that humans show a wide variety of responses to magnetic fields which have frequencies corresponding to physiological rhythms. The most widely replicated effects demonstrated under laboratory conditions have been those amenable to electrophysiological recording techniques, especially electroencephalographic (EEG) activity: for example, Bell, Marino, and Chesson (1994) found that the peak frequency of a person's EEG was altered by application of a magnetic field to match the frequency of that applied field. In addition, there is an increasing body of literature showing that weak, low-frequency magnetic fields can also affect higher cognitive functioning. Application of magnetic fields have been associated with decreased thresholds of pain perception (e.g., Papi, Ghione, Rosa, Del Seppia, & Luschi, 1995), increased reaction time (e.g., Whittington, Podd, & Rapley, 1996), increases in time estimation (e.g., Cook, Koren, & Persinger, 1999), and decreased performance in recognition memory tasks (e.g., Podd, Abbott, Kazantzis, & Rowland, 2002). A comprehensive review of recent research into electrophysiological and cognitive effects can be found in Cook, Thomas, and Prato (2002), and in Cook, Saucier, Thomas, and Prato (2006). Having said that, it is true that most of the observed behavioral effects are relatively small, and it could be argued that they would be unlikely to have significant effects outside of the laboratory environments. However, two areas stand out as being of more relevance to real-life situations: those showing changes in performance in attentional tasks and those showing changes in emotional state.

Magnetic field effects and performance in attentional tasks

The studies showing effects of magnetic fields on performance in attentional tasks should be of particular interest to ecopsychologists as this is one factor that is often used to demonstrate the effect of a "restorative environment"—generally defined as a place associated with the recovery to baseline levels of functional resources and capabilities that have been diminished through stress, overuse, or understimulation (Hartig & Staats, 2003). In environmental psychology, this restoration process is attributed to certain properties of the specific environment, some immediate and some associational. For example, Kaplan's (1995) attention restoration theory (ART) includes the qualities of (a) "being away" from the demands of regular life; (b) having a "soft fascination," that is, sensory aspects of the environment that have an (possibly evolutionary-based) inherent appeal; (c) "extent or scope," a sense of vastness or connection between the experience and one's knowledge of the world. According to the literature (for a review, see Ulrich et al., 1991), restorative environments tend to equate with natural settings rather than urban or built ones. However, in bioelectromagnetics, similar differences in performance have been found when comparing the presence or absence of 50 Hz (a common power-line frequency) magnetic fields (e.g., Crasson, Legros, Scarpa, & Legros, 1999). Rather than the attributional or sensory-engagement qualities used to explain psychological restoration, the given explanation is that the magnetic fields bring about activation of frontal and parietal cortex regions of the human brain, particularly during tasks of executive function (Cook et al., 2002). Decreases in sustained-attention performance are in part attributed to this increased activation adversely affecting reaction times, an effect that has been widely found in bioelectromagnetics research.

Magnetic field effects and restorative environments

Could there be a meaningful relationship between the effects seen from magnetic field exposure and those classed as due to restoration? There may be a direct link with restorative environments in that the real-life magnetic field environment will also tend to show a split between natural and urban settings. The former tend to have much lower intensity magnetic fields than the latter (urban magnetic "noise" is typically 0.5 μT and above, whereas natural settings are 0.1 μT or less), with a different frequency spectrum (urban settings shift toward higher frequencies, peaking at power-line operating frequencies of 50 or 60 Hz; natural settings would tend to be characterized by fields under 20 Hz, peaking toward the lower end). The bioelectromagnetics literature would thus suggest that some urban settings could equally well be described as "deteriorating" as the natural settings being "restorative." However it is viewed, the magnetic fields present in urban and natural environments could well be a previously overlooked factor involved in whether an environment will be restorative.

Having said that, while the presence or absence of certain magnetic fields may be considered to play a role in human reaction to specific environments, this can only be one of many factors, given that much of the environmental psychology literature shows that restoration can occur with visual stimuli alone. For example, Berto (2005) showed that participants, initially mentally fatigued by performing a sustained attention test, improved their performance on a final attention task after they had merely been shown photographs of restorative environments as opposed to ones of nonrestorative environments or geometrical patterns. However, there is another possible link: the presence of magnetic fields also appears to relate to changes in emotional state.

Magnetic field effects and emotional state

Some of my own research has focused on emotional responses to weak, low-frequency magnetic fields, exploring how such fields alter concurrent perceptions to change the emotional aspect of an experience. In one such study (Stevens, 2001), it was shown that an artificially applied 50 μT magnetic field oscillating at 20 Hz could alter participant ratings of the affective quality of 20 concurrently presented images. The study employed a double-blind design and showed that participants gave significantly lower average rating of the images in the control condition than in the applied magnetic field condition, with the suggestion that the presence of the magnetic field influenced participants to perceive the various images as being associated with more positive emotions.

In a second study (Stevens, 2007), it was further shown that, when blind-exposed to a 5 μT magnetic field at frequencies corresponding to the EEG α-band frequencies (8–12 Hz), participants seated in a dim, uninteresting room reported a change in emotional state even in the absence of any specific sensory stimuli. Further analysis showed that this related to a global decrease in brain electrical activity but lacked the specific physiological indicators that would suggest the magnetic field was directly inducing an emotional state. Instead, it was concluded that the participant experiences of emotional states were instead due to an *interpretation* of the effects of the magnetic field. That is, they were aware on some level of a general physiological change (the direct effect of the magnetic field) and had to find an explanation for it. In the absence of any external cues, they opted for the interpretation of "decreased physiological activity" as being due to a more positive emotional state.

Magnetic field effects and place attachment

If we apply these emotion-related findings to the reactions we might expect at a specific location where such lower-frequency fields are naturally present, then this suggests that magnetic fields could alter the emotional relationship between people and a specific place, that is, they may also play a small role in place attachment (Jorgensen & Stedman, 2001). How might this work? Based on the interpretative nature of the effects described above, we would obviously have to take the context of the place into account. The studies described above both found the magnetic fields to be associated with a more positive (or at least less negative) emotional perception, so this would be the default if the specific place did not have any prior strong emotional associations. If such sites had stronger-than-normal magnetic fields, they might then be perceived as happier or more comfortable, or maybe even (depending on the psychological make-up of the individual) as "sacred" or spiritually significant. Indeed, Krippner, Devereux, and Fish (2003) report evidence that some megalith sites made specific use of aligned magnetic stones in their construction, offering some support to this idea.

However, if the place had sensory elements which are stereotypically associated with less-pleasant emotions, then any magnetic field–related change in physiological arousal could be interpreted as a negative emotion, giving rise to a more unpleasant experience. For example, several studies have suggested that magnetic fields with similar properties to those used in my experiments (Stevens, 2001, 2007) may play a role in making people think specific places are unpleasant or even "haunted" (Braithwaite, 2004; Braithwaite & Townsend, 2005; Wiseman, Watt, Stevens, Greening, & O'Keeffe, 2003). In those studies, the fields in question arose from combinations of natural and artificial (electrical wiring) sources. The Wiseman et al. (2003) study showed a significant difference in the variance of the blind-measured magnetic fields between control areas and those in which "haunting" experiences had historically been reported. Moreover, a significant relationship was found between the variance of the measured magnetic field and the number of unusual or unpleasant experiences reported by experimental participants allowed time in each. The Braithwaite studies (Braithwaite, 2004; Braithwaite & Townsend, 2005) measured magnetic fields at sites associated with reports of emotionally unpleasant or otherwise anomalous experiences, finding qualitative difference in spatial distribution and variance of the magnetic fields when compared to control sites in the vicinity. Braithwaite also showed that the baseline geomagnetic levels in the vicinity were much higher than average, suggesting the presence of a geological magnetic anomaly in the area in addition to dynamic qualities of the measured magnetic fields.

Recommendations for (Eco)psychologists and Therapists

So what does this mean in practical terms? First of all, it highlights the idea that it is worth considering that physical as well as psychological factors may influence our responses to any environment, possibly even contributing to whether that environment will be perceived as restorative. Whether you are designing a therapeutic environment, or trying to evaluate factors contributing to specific psychological states, it is often worth considering how people's bodies and minds might be responding to a range of physical variables, including the given example of magnetic field responses. While for many of these variables it is possible to obtain equipment to give direct measurements (e.g., relatively inexpensive, hand-held meters are available that would give an indication as to the relative intensities of the magnetic environment at different locations), observation of the environment, including an awareness of a landscape's story, is perhaps a more useful approach.

Even a cursory reading of the available literature will give a better feel for the importance of often overlooked, physical aspects of any environment. In terms of magnetic fields, look around for indications of specific physical features: nearby power lines or electricity substations would give elevated levels of magnetic field; lack of other animals where you would normally expect them is an obvious sign that something is unusual (this includes anecdotal reports of areas where migratory birds get lost or confused as this is a well-documented effect indicating the presence of a localized magnetic anomaly in the region: Wiltschko & Wiltschko, 1996).

There are also other physical factors to consider. Any location prone to rapid changes in physical conditions due to climatic conditions or local morphology can produce a variety of perceptual and behavioral changes. For example, Persinger (1980) reports changes in blood pH, blood pressure, and tissue permeability in response to a rapid temperature decrease (e.g., due to wind funneling, presence of moving water, etc.); Rosen (1979) notes that humans are sensitive to dynamic pressure variations and that the specific physical structure of a place affects the propagation of pressure waves through it. Even simple cues like the presence or absence of plant life could indicate the presence of elevated or depleted levels of chemicals and minerals that could also affect human functioning (e.g., using the presence and diversity of lichen as an indicator of air quality: Loppi & Frati, 2006).

Second, there are also emotional/interpretational responses to physical factors to consider. While, generally speaking, reactions to a given location are going to be governed by the more obvious aspects of that location—the visual cues, subjective expectations, associational memories, and the like—it would be worth considering physical variables in cases where there are inconsistencies between different researchers' findings or apparently incongruous subjective reactions to a specific location. In such instances, you might ask local people about or look up any reports of anomalous experiences such as stereotypical "haunting" or specific folkloric accounts and traditions: while interpretations of features can vary wildly, the existence of such accounts can be an indication that people are being affected by something related to the location. One very clear example of this is given by Tandy (2000; Tandy & Lawrence, 1998). He reports experiences relating to pressure-based effects, describing two instances of sites in which people consistently experienced feelings of fear, unease, and nausea[3] in response to 19 Hz pressure waves ("infrasound"). In one case (Tandy & Lawrence, 1998), these waves originated from a misaligned ventilation fan, while in the other (Tandy, 2000) the waves resulted from the physical dimensions of a specific corridor.

Conclusion

Whatever our psychological state, the physical connections we have with the rest of the natural world are always there and cannot be meaningfully broken. This suggests an alternative way of conceptualizing some of the environmental and personal difficulties we face—one that might help people appreciate their place in the world. While it can be a powerful and often successful metaphor, emphasizing the need for reconnection (e.g., Macy & Brown, 1998) implies a process that requires a lot of effort while reifying the original notion that a human–nature separation exists. For the ecologically minded psychologist or therapist, it also highlights the problem of finding ways to motivate people to achieve something that they may not have felt the need for in the first place! However, if we can become aware of our physical connections, we have a preexisting framework on which to build. The examples given in this article show that our connections to the natural world are only "lost" to our conscious minds. Even if we are unaware of them, our bodies, thoughts, and behaviors are still affected by both sensory and nonsensory stimuli from the environment within which we are embedded. In turn, this will alter our perception and emotional associations of that environment in ways that would not easily be explained through conventional sensory interactions or psychological interpretations. While the purely physical aspects are unlikely to be the primary component of any relationship with a specific environment, factors which can change attentional ability and emotional state (as illustrated by the magnetic-field examples given in this article) would have obvious relevance to the concepts of restorative environments and place attachment. It is hoped that an increased awareness of such physical connections and our embedded nature might generate novel insights in the reader into the complex relationships between people and place.

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Notes

1. Traditionally the term *embedment* has only been used in mechanical engineering to denote where surfaces of a loaded joint flatten against each other to relieve stresses. However, in its wider connotations, the state of being embedded is, I think, a useful concept for ecopsychologists to think about.
2. The tesla (T) is the unit of "magnetic flux density," essentially a measure of the strength of a magnetic field. Bioelectromagnetics more commonly expresses fields in millionths of teslas or microtesla (μT) given the weak fields typically encountered. For example, a hairdryer at a distance of 3 cm has a field of up to 2,000 μT, a fluorescent light up to 800 μT, and the typical background field (from natural and artificial sources combined) that we experience in everyday life is around 0.10 μT (source: World Health Organization, http://www.who.int/peh-emf/about/WhatisEMF/en/index3.html, retrieved December 13, 2006).
3. Certain individuals even experienced a more direct resonance between the waves and their eyeballs, resulting in visual disturbances. Combined with the negative emotions, this led to a belief that the area was haunted: a surprisingly common conclusion at the present time. For example, the most recent survey by the Baylor Institute for Studies of Religion (2006) found that 37.2% of Americans believed that "a place can be haunted," whereas 21.5% had "visited or lived in a house or place believed to be haunted."

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