MOUNTING EVIDENCE THAT MINDS ARE NEURAL EM FIELDS INTERACTING WITH BRAINS

Abstract: Evidence that minds are neural electromagnetic (EM) fields comes from research into how separate brain activities bind to form unified percepts and unified minds. Explanations of binding using synchrony, attention and convergence are all problematic. But the unity of EM fields explains binding without these problems. These unified fields neatly explain correlations and divergences between synchrony, attention, convergence, and unified minds. The simplest explanation for the unity of both minds and fields is that minds are fields. Treating minds as the fields' underlying, intrinsic nature has the further virtue of avoiding mind-body problems. There's also rising evidence that EM fields interact with brains. McFadden argues here that fields help shift the focus of attention by initiating synchrony in different neural networks, which boosts their own fields and thereby binds their activity. This evidence that minds are fields that bind and guide brain activities supports free will over epiphenomenalism and supervenience.

1. Evidence that Minds are Electromagnetic Fields

1.1 Introduction

Since the 1920s, field theories of mind have seated minds in the electromagnetic fields of brains. These EM fields arise mainly from electrical impulses in neurons, which travel down axons via their membrane channels. This ultimately creates synaptic signals to other neurons. The electrical impulses typically occur in bursts, causing oscillations of a certain frequency that are reflected in the fields. These fields resemble the mind's activities in various ways. For example, sensory images arguably arise from discrete neurons in field-like ways as continuous, unified wholes spread intangibly across space (Libet 1994). These theories have proliferated because they draw on considerable experimental evidence, withstand criticisms,[1] and offer ways to avoid neuroscience's problems in explaining minds purely by synaptic links (Jones, 2013).

One such problem is the binding problem. Color and shape are processed by separate neurons, so it's unclear how they bind to form a unified, conscious[2] percept of a colored shape. It's also unclear how percepts bind with thoughts and feelings to form our overall, unified experience. Most neuroscientists attribute binding to synchronized firing by neurons, hierarchical convergence of neurons, or focal attention, we'll see. Yet each has serious problems. This paper tries to avoid these issues by modifying JohnJoe McFadden's (2013) important idea that binding is achieved by the brain's conscious electromagnetic field.

Below I will start by examining evidence that binding involves EM fields. Such evidence will help in arguing that minds are fields. Then I will review evidence that these fields interact with brains. This will help in arguing that minds interact with brains. (More basic accounts of field theories of mind appear in my 2013 survey. That paper discusses, for example, why minds aren't affected by fields from outside brains, what keeps minds separate, whether only EM fields are conscious, and how various qualia and images arise.)

Another problem facing neuroscience is the mind-brain problem. It arises because standard mind-brain theories like reductionism and dualism face serious issues. I'll try to avoid these issues (in §3.3) by arguing like Bertrand Russell and others that we perceive objects indirectly by sensory organs, instruments, reflected light, etc., so we can't know their underlying reality behind these sensory appearances. Since we don't know the underlying reality of brains, for all we do know minds could reside here. Specifically, minds may be the underlying reality of neural EM fields. In this sense, minds are neural fields, that is, the two are identical in reality which underlies appearances (n.b., minds are wholly conscious here).

1.2 Problems in Binding by Synchrony

The leading view today is that the binding of simple perceptual features (e.g., moving shapes) into complex forms involves spatially segregated neurons firing in synchronized lockstep. This supplies a temporal code for binding. For example, Gray et al. (1989) originally showed that synchronization occurs in cat primary visual cortex (V1). Neurons there fired in phase in response to stimuli patterns moving together in coherent ways. Roelfsema et al. (1997, p. 157) reported that in tasks requiring focused attention, synchrony appeared across various cortical areas "without time lags" in awake cats. This zero-time lag has become an identifying mark of synchrony.

Fries et al. (1997) showed that conscious perceptions by awake cats correlate with synchrony in V1 during binocular rivalry conditions. Fries went on to argue (2005) that inputs to neurons are most effective if they arrive when neurons are potentially excitable, and this is best achieved by neurons firing in synchrony. Synchrony produces flexible neuronal networks that effectively communicate to influence downstream activities. Synchrony is thought to play a role here not just in simple feature binding, but also at higher levels of multi-sensory integration, memory, and motor coordination (Singer, 2004, 2007).

Synchrony is also linked to attention. Attention selects items for further processing, and it's closely tied to consciousness (e.g., Engel et al., 2005). Bauer et al. (2009) demonstrated an actual causal link between synchrony and attention. They showed that a preliminary flicker at a target location enhanced subsequent detection of the target by human subjects. While the flicker itself was too fast to detect, it created synchrony in cortical neurons responding to the flicker site. This subliminal flicker enhanced target detection by attention.

Yet binding by synchrony is controversial. Thiele and Stoner (2003), Dong et al. (2008), and others found that feature binding and synchrony don't correlate. Hardcastle (Journal of Consciousness Studies online thread: imprint.co.uk/online/hard.html) noted that while Gray and Singer's (1989) data show that shape-responsive neurons synchronize, shape and color neurons failed to synchronize: "if the cat was shown a blue square, they did not find any color-responsive neurons oscillating with the shape-responsive neurons". Also, Koch et al. (2016) point out that synchrony occurs without consciousness during anesthesia and seizures. Here hypersynchrony seems to disintegrate binding.

Binding by synchrony also faces theoretical issues. Here are well-known examples:

(1) Shadlen and Movshon (1999) doubt that neurons can distinguish synchronous from asynchronous inputs. Each neuron receives hundreds of excitatory inputs for each one signal it

emits, so inevitably these inputs will arrive in apparent synchrony. It's thus unclear how the neuron can ascertain which inputs are relevant to binding.

(2) This same paper adds that which features belong to which objects often isn't clear until higher processing. So higher detectors must "determine which inputs carry signals worthy of further computation" (ibid., p. 69). But it's unclear how synchrony can do this.

(3) Prinz (2012) notes that if a perceived shape has both red and white areas, then color neurons will synchronize and bind not just with shape neurons, but also (oddly) with each other.

(4) Goldfarb and Treisman (2013) note that binding by synchrony involves neurons firing in synchrony when they encode separate features of the same object. They add that "if . . . the same letter shape appears in different colors in different locations . . . [then] synchrony can represent which shape is in each location, and it can also represent which color is in each location; however, it is impossible to simultaneously synchronize both the colors and the shapes in all their locations" (ibid., p. 267). Synchrony alone doesn't explain binding here.

(5) Merker (2013, p. 403) cites evidence that synchrony balances inhibition and excitation to avoid "runaway excitation/seizure" in neurons. He adds that problems like those above suggest that synchrony has no additional role in binding cognitive activity. Synchrony is like blood flow: both maintain tissues and covary with cognitive activity, yet play no direct role in cognition.

(6) Merker (2013) also argues that synchrony is registered only by its effects on neurons' synapses, so it's unclear how binding by synchrony differs from binding by neurons converging. It might be added that unless binding by synchrony involves binding by converging neurons, even neurons in different brains could synchronize and bind.

1.3 Problems in Binding by Attention

Attention helps us interpret perceptions, and it's arguably tied to consciousness, for example, when we scan a crowd and suddenly become conscious of a friend's face there. Crick and Koch (2003, p. 121) argued that we need attention to select which binding interpretation is correct (disambiguation), and this "embodies what we are conscious of".[3]

Yet attention and consciousness can diverge, as Tsuchiya and Koch (2008) point out. Fei-Fei et al. (2007, p. 1) found that "within a single glance, much object- and scene-level information is perceived by human subjects" as real-life photos are flashed before them with no explanations of their content. Attention is too localized to get all this in a flash. Such evidence of consciousness without attention dates back to Sperling (1960). Yet even ordinary experience shows that we're not totally blind of the surrounding crowd as we focus on the friend's face.

The relevant criticism is that binding can occur without attention:

(1) Treisman (2003) showed that normal subjects experience illusory conjunctions if the focusing of attention is foiled by presenting letters just briefly. For example, they reported seeing a red T when a green T and red O were shown simultaneously. Attention can help disambiguate these illusions. But LaRock (2007, p. 759) makes the important observation here that "these normal individuals have still performed the function of binding, albeit of an illusory conjunction sort. Therefore, focal attention is not necessary for binding," counter to Crick and Koch. Simple features can bind into a conscious, unified percept without attention and its disambiguations.

(2) Arguably, binding also occurs if attention is turned off due to fatigue. Ordinary experience suggests that we're not unconscious then, for we can see colored shapes. Yet we just see them blankly without conceptualizing them. Here again simple sensory features may bind to form conscious patterns pre-attentively.

1.4 Problems in Binding by Convergence

In another approach to binding, hierarchies of feature detectors converge on increasingly general detectors, thus unifying many simple features into an overall object (e.g., a face). For example, Eric LaRock (2007) says that while synchrony and/or attention disambiguate perception, binding actually occurs by convergence, often pre-attentively. He builds on Lamme (2004), who offers evidence that perception involves not just ascending signals in processing hierarchies, but also recurrent signals feeding back to lower cortex – with only the latter becoming conscious. This yields raw colored shapes from pre-attentive feature binding in lower cortex, and finally meaningful experiences tied to attention and global access. LaRock adds that detectors in the inferior temporal cortex identify objects stored in memory, and feed back to lower cortex to establish unified, spatially organized percepts.

This has the virtue of explaining how objects get both their structure and meaning. Yet binding by convergence faces a difficulty. Many perceived objects are novel, as LaRock admits (p. 767). This suggests the existence of potentially infinite detectors for all these objects, which may be unrealistic.

1.5 Field Theories Avoid Binding Problems

Field theories can avoid the binding problems specific to each theory above. But let's start with how they can also avoid three problems the theories above tend to share. These problems tend to arise because the theories explain neural communication in terms of synaptic connections (recall Merker's final comment on synchrony above).

(1) Color and shape pathways lack systematic synaptic connections. They're segregated and parallel in V1, and in areas that V1 feeds into (Zeki, 1993). Additionally, "there are few, if any, direct connections between V4 and V5" that process color and moving shapes, respectively (Zeki, 2003, p. 216). Also ascending projections for color and shape exhibit only limited instances of convergence, so that they largely preserve their separate identities with minimal overlap (Shipp and Zeki, 1995). All this makes it hard to see how color and shape pathways can bind to form colored shapes in images. However, in field approaches electromagnetic fields can reach across pathways to pool information into a unified, conscious whole. This can be achieved, for example, in cortical maps like V1 where color and shape elements for each point in an image are nearby (Jones, forthcoming #2). The same applies to binding generally. Zeki (1993, p. 296) says, "there is no single cortical area to which all other cortical areas report exclusively, either in the visual or in any other system." Again, the brain's single field can bind these cortical activities together.[4]

(2) Transmissions of synchrony between brain areas with zero-time lag is difficult to explain in synaptic terms, for the speeds of synaptic transmissions from a common source vary with distance (McFadden, 2013). By contrast, field transmissions occur at light speed. More

generally, fields may account for our fleeting, flexible experiences better than any synaptic architectures can, for fields arise from fixed neuronal structures like intricate music arises from a fixed orchestra (to adapt Fingelkurts et al., 2010).

(3) Synaptic accounts face difficulties in explaining smooth areas of color in images, for neurons, molecules, etc. are discrete and grainy. By contrast, strong fields are continuous versus grainy – their quanta form an inherently unified probability cloud of continually high energy.

Field theories can also avoid the specific problems in each binding approach above. McFadden's field theory (2013) is crucial here. To start with, he argues that we're unaware of information in neurons until the brain's conscious EM field binds the information into a unified, conscious form. Synchrony just plays an indirect role by amplifying these fields (pp. 156f.). When neurons fire asynchronously, peaks and troughs in their oscillations aren't in phase, so their fields tend to cancel out. But with synchronous firing, peaks and troughs reinforce each other to create a strong EM field oscillation (p. 157).[5] The reason we only see a camouflaged grasshopper after we focus attention on the area is that synchrony (which accompanies attention) creates a strong field that binds neuronal information into a unified, conscious percept.

This elegantly explains the correlations between synchrony, attention and consciousness in terms of binding by fields. McFadden proceeds even further here by showing that not only does synchrony reinforce fields, but in turn fields promote synchrony (p. 162f.). He points to experiments (outlined below) which show that applying external fields to neuronal networks slows their oscillations and makes them synchronize. The fields thus help shift attention from one area to another – they promote synchrony in the new area, which reinforces the field in the new area, thus binding neural activity into a unified, conscious form.

McFadden's arguments are important because they marshal evidence that fields can unify and guide brain activities, and that synchrony, attention and consciousness are linked to strong fields. He also argues that the brain's field has an inherent unity in that it reaches instantly (with zero-time lag) across circuits and binds their information into a single conscious whole akin to a dimensionless point (p. 164).[6] For all these reasons, the mind seems to be seated in this field.

Field theories can avoid theoretical problems in binding by synchrony concerning which elements bind with which others to create objects and overall scenes. Here they can explain perceptual binding in terms of fields in cortical maps, as above (for further explanations, see the end of Jones, forthcoming #2). Binding by synchrony also faces the problem that binding of colors and shapes occurs without synchrony in some studies above. But binding can still correlate with fields here. For some binding by fields can arguably occur when fields aren't at full strength due to synchrony (see also Fingelkurts et al., 2010). One example is when highly active color and shape pathways are nearby in cortical maps. Furthermore, hypersynchrony occurs without binding during anesthesia and seizures. But binding can still correlate with fields here. For fields can't effectively bind sensory features together when hypersynchrony stymies feedbacks for color constancy, perceptual grouping, etc.

This approach can be further supplemented to avoid the problems in binding by attention. To fit the evidence above of pre-attentive binding, three binding levels can be posited. (1) When neurons fire out of phase, their fields cancel out and neural binding does not occur. (2) At pre-attentive levels in lower cortex, recurrent signals accompanied by increased activity or synchrony can fortify fields and bind processing into raw colored shapes that are conscious. (3) At attentive levels in higher cortex, strong fields in synchronous activity bind raw colored shapes to concepts, yielding meaningful objects like grasshoppers. So, the brain's field binds all cognitive activity into a unified, conscious (though structured) form.

This approach can also avoid the problem in binding by convergence. Field theory doesn't require infinite top-level detectors to bind information into conscious, unified objects. Binding into colored shapes is achieved (as just noted) by fields in neural maps pre-attentively. Top detectors just recognize some of these shapes as meaningful.

In these ways, field theory explains the correlations and divergences between synchrony, attention, convergence, and unified consciousness, while avoiding the issues in other binding theories. This is good evidence that EM fields bind cognition into a unified, conscious form. Further evidence for field theory is in §2 below.

This evidence can help arguments that minds are fields. To start with, it's the inherent unity of fields that enables them to bind cognition. Both minds and fields are characterized by this inherent unity. The unity of minds is evident in how perception, emotion and thought can fuse into an integrated whole. The unity and continuity of fields was explained above. The simplest explanation for this mind/field affinity is that minds are fields. Moreover, treating minds as the underlying reality of these fields avoids perennial mind-body problems. Other respectable field theories exist. But only this one precludes (for example) problematic epiphenomenalism and emergentism. So this may be a particularly defensible interactionist field theory (see §3.3).

2. Evidence that Electromagnetic Fields Interact with Brains

2.1 Introduction

We'll now shift from evidence that minds are neuroelectromagnetic fields to evidence that these fields interact with brains. These views will support mind-brain interaction below. The latter can be characterized by views opposed to it. For example, it's often held today that physical events are causally closed (i.e., they only have physical causes). Similarly, epiphenomenalists hold that brains produce minds, but minds lack their own causal powers (compare supervenience, §3.1). So when we walk through city streets shopping, information is processed nonconsciously by our neural circuits, which enables us to navigate and shop. These nonconscious circuits also produce our consciousness, but the latter has no more affect on our shopping than our shadows do.

Arguably, one source of evidence for epiphenomenalism is that neuroscience's accounts of brain activity don't refer to consciousness or qualia. But neuroscience is actually so far from explaining thought, planning and volition that there's no evidence here for epiphenomenalism. Other evidence for epiphenomenalism is arguably that nonconscious readiness potentials precede conscious decisions to act (Libet 1985). Yet this evidence is controversial, for it may just point to, for example, accumulating neural noise, or the start of forming an intention to act. Moreover, this evidence is quite limited, for it applies simply to motor control, not higher, deliberative volitions like navigating and shopping (Pockett, 2006). Indeed, if we look at this higher cognition, there is evidence that fields bind and guide brain activity, and that these fields are conscious – counter to epiphenomenalism.[7]

Interactionists typically feel that epiphenomenalism demeans humans as autonomous agents. If our actions are determined by nonconscious neural circuits, then we aren't acting on our conscious plans and aspirations. Our autonomy may be saved if conscious fields interact with brains. We'll return to this after covering recent, mounting evidence that EM fields do interact with brains (some of which McFadden also reviews). 1Tiganj et al. (2014), 2Goldwyn et al. (2015), Maeda et al. (2015), and Scholkmann (2015) aren't covered below due to space limitations.

2.2 Frohlich and McCormick (2010)

This paper noted that prior investigations of how external fields affect neurons typically involved unnaturally strong fields or dense neuronal arrays in rodent hippocampus (pp. 139f). By contrast, Frohlich and McCormick investigated whether the weak electric fields generated spontaneously by cortical neurons can act back on these neurons to affect normal cortical operations. Initially they applied a weak external sine wave field to in vivo brain slice preparations of ferret visual cortex. This external field, which was similar in strength to the in vivo field, caused small membrane depolarizations in the in vivo neurons. This accelerated their slow in vitro oscillations and made them more periodic, that is, it entrained these oscillations (pp. 132ff.). To insure that this synchronization wasn't an effect of just the sine wave field, they showed that a field with naturalistic waveform also entrains the in vitro oscillations (pp. 135ff).

On this basis, the authors hypothesized that there's a feedback loop in which endogenous fields affect the neurons that generate them. This loop thereby "modulates and guides neuronal circuit activity". They tested this idea by calculating the endogenous in vitro fields, then applying external fields with either positive or negative strength that reinforced or counteracted the endogenous field. These experiments showed, as predicted, that the positive feedback enhanced the oscillations while the negative feedback suppressed the oscillations (pp. 136f., 140f.).

Finally, they developed a computer model of a neural network which "confirms that such . . . perturbations of the membrane voltage can indeed alter the macroscopic network dynamics" (p. 139). They concluded that "feedback interaction between structured neuronal activity and endogenous EF [electric field] can occur in neocortex and may play an important role in shaping normal physiological network activity" (pp. 139f.). Furthermore, "such a proposed global feedback signal could serve as a network-wide synchronization signal" (p. 129).

2.3 Anastassiou et al. (2011)

This paper noted that prior studies showed how constant fields of modest amplitude across millimeters may affect neural activity. Yet they didn't address effects at the membrane level of single neurons. So the authors developed a 12-electrode setup to record activity between and within rat cortical pyramidal neurons inside in vitro slices. Synaptic transmissions were pharmacologically blocked while a weak external electric field (similar to the endogenous fields) was initiated at one electrode. This caused the subthreshold membrane potentials of nearby neurons to oscillate at the same frequency as the external field. (pp. 217ff.).

To see how this weak external field affected a firing neuron, current was injected into individual neurons to induce spiking while the external field was applied. The spiking phase locked with external field oscillations. Boosting the field enhanced phase locking (pp. 218ff.).

To test whether this external field could synchronize large numbers of neurons, the field was positioned near four neurons (again with synaptic transmission blocked). As in the single-neuron case above, the external field caused the neurons to synchronize their spikes (220f.).

The authors conclude (p. 222) that "potentials induced by oscillating electric fields . . . serve to synchronize neuronal activity", and that this synchronization "may have a substantial effect on neural information processing and plasticity".

2.4 Hales (2014)

Colin Hales reinforces the conclusions above with an intricate computer model which indicates how fields interact with neurons. He offers impressive evidence about how the brain's electromagnetic field originates, and how it interacts with neuronal signaling.

Hales (pp. 323f.) specifies three component fields that the brain's electromagnetic field derives mainly from: (1) the huge, static, background electric field from neuronal membranes; (2) the fast, dynamic electromagnetic field created over large distances by pulsating currents in membrane channels with dipoles; (3) the slow, persistent electric fields created by clumps of channels that synchronize into coherent forms over a big area to create temporary, weak dipoles.

The paper mainly explores the coherent fields produced by channel currents (2-3 above). These dominate the brain's dynamic field system. Here Hales uses computer models of channel activity in an active CA1 neuron from rat hippocampus (pp. 329, 333). He develops equations to describe field behavior in channels, including equations for the Lorentz force as an EM coupling mechanism in which the field affects nearby fields and currents (pp. 322f., 329-33, 354).

Experiments with these models show that each firing of this neuron bathes it in a large, rotating electric field – a sweeping "lighthouse illumination" – which can modify the neuron's transmembrane potential, and also alter the charge environment of neighboring cells (pp. 342-4). This channel activity thus seems to produce a Lorentz force in which electromagnetic fields act back on the cells producing them. These effects, "with sufficient synchrony between nearby neurons, could add up to become . . . capable of modifying firing thresholds" (p. 343).

These experiments undermine traditional claims that the brain's field comes from intra- and extra-cellar currents (pp. 316f., 348f.). Instead the coherent fields produced by channel currents dominate the field system: "ion channels, by virtue of their large numbers spread spatially over the cell surface, through their . . . pulsing/reversing dipoles, can deliver a spatially large and unified dynamic electric field and magnetic field system" (p. 349).[8]

These experiments, in addition to other recent works Hales cites (p. 315), undermine traditional claims that the brain's electromagnetic fields are epiphenomena of neuronal activity. Instead, these fields can affect neuronal activity. The "lighthouse illumination" above indicates that multitudes of cells can synchronize into a complex interplay of EM couplings (p. 349).

2.5 Anastassiou and Koch (2015)

According to this review paper, recent experiments like those above show that even weak endogenous fields entrain spikes in neural networks within in vivo slices, firmly suggesting that fields affect in vivo rhythms. Also, recent computer models show that extracellular fields tend to synchronize network activity and alter signaling in neural networks.

They conclude that this research should be vigorously pursued (especially in regard to investigating neural functions and computations in normal brain activity) because it "has significant implications on our understanding of brain processing" (p. 95).

3. Interactionism Versus Epiphenomenalism and Supervenience

3.1 Introduction

In the following pages, six arguments will support interactionism over epiphenomenalism and supervenience physicalism.

(1) Most field theorists argue that minds are electromagnetic fields in brains (§1.5), or they're linked to these fields (§3.2), and these fields actually interact with brains (§2.2ff.). Given the evidence above, this argument strongly challenges epiphenomenalism.

(2) Epiphenomenalists can accept that fields interact with brains, but contend that minds arise as epiphenomena from fields. Yet, in what may be a particularly defensible field theory, minds are fields (the underlying reality of fields), so minds don't emerge from fields (§3.3).

(3) In this particularly defensible field theory, cognition must arise consciously versus nonconsciously, for conscious fields are what *bind simple processing into fully developed forms* (recall §1.5). So cognition can't operate nonconsciously as epiphenomenalism requires (§3.3). Here minds are wholly conscious fields acting on neurons to bind processing into a unified form.

(4) Interactionism seems more plausible than epiphenomenalism on various evolutionary grounds (§3.2).

(5) Epiphenomenalism involves the emergentist claim that experience emerges from nonexperiential brain activity in ways physics can't explain. Strawson (2006) replies that life forms can intelligibly emerge in virtue of self-replicating abilities in molecules, but this "in-virtue of" relation is lacking if experience pops into existence from what lacks experience. The latter is unintelligible, it's magic where anything goes. (This just rejects emergent experience, not emergent causality in experience.) The particularly defensible field theory above avoids emergentism (§3.3).

(6) Field theories can also threaten the supervenience physicalist claim that minds don't change without corresponding neural change. To start with, interactionists feel that we're autonomous agents, not puppets determined by external factors beyond our conscious control. But if field theorists say that the activity of conscious neural fields is wholly determined by electrodynamics, then we are just puppets of laws of physics outside our conscious control. Our autonomy is saved only if – against supervenience – neural field activity is partly determined by consciousness working autonomously of physics. Field theories can deliver this autonomy. This blocks both supervenience and influential "manipulation arguments" which argue against free will (as self determination) based on assumptions that minds are puppets of external laws of nature (§3.3).

We'll now look at viable interactionist field theories. Most draw on the arguments listed above. The particularly defensible field theory above draws on all six arguments.

3.2 Dualist Field Theory

Dualism usually treats minds as nonphysical, in contrast to brains. This differs from physicalism where all that exists is physical.[9] Dualism is often criticized today. But Lindahl and Arhem's (1994) sophisticated dualist field theory may defuse many standard criticisms. Their epistemic dualism differs from the (perhaps more usual) dualism above in that minds are treated as subjective, and bodies as objective. Also their dualism is interactionist in contrast to parallelist and epiphenomenalist dualisms which preclude interactionist field theory.

Interactionist dualism faces criticisms about how radically different minds and brains can interact, and whether this interaction is reconcilable with physics. But one way that Lindahl and Arhem (1994, pp. 113ff.) address these issues is by treating EM fields as intermediaries between the conscious mind and the brain's action-potential patterns. Building on Popper's ideas, they say that critics of interactionism have outdated views of causation that require contact of spatially extended bodies, like billiard balls colliding. Instead consciousness interacts with action-potential patterns through the mediation of nonconscious neural EM fields. This force field isn't radically different from minds, for Newtonian forces are vectors that have magnitudes in a direction, yet are arguably incorporeal and unextended in space like minds.

To explain how minds trigger nerve impulses, Lindahl and Arhem (forthcoming, §3) draw on Popper's view of De Broglie's pilot waves, which carry particles in deterministic ways, in contrast to indeterministic views of quantum mechanics. Empty pilot waves aren't associated with particles and don't carry momentum or energy. Reiterating Popper, Lindahl and Arhem point out that in some interpretations, empty pilot waves can interfere with non-empty, energy-carrying waves. This suggests "the possibility of non-energetic influences upon energetic processes" such as membrane potentials poised at their firing threshold.

They also note that dualists often construe causation as regular conjunctions of perceivable events. So no particular difficulty arises from some events being conscious and others being neural, so long as they're regularly conjoined. While simple regularity accounts are criticized for treating even coincidences and other accidental factors as causal, Lindahl and Arhem (forthcoming, §3) avoid such problems by refining the INUS condition.[10] They conclude that nothing can rule out here that subjective minds and objective brains can interact.

In this dualism, minds interact with brains and are autonomous of physical laws. So this is an alternative to epiphenomenalism and supervenience physicalism. Yet epiphenomenalism isn't wholly precluded, for the nonconscious fields in this dualism could arguably create minds as epiphenomena. Still, interactionism seems more credible here than epiphenomenalism on evolutionary grounds. To start with, the standard evolutionary argument is that for consciousness to have evolved by natural selection it must have affected animal behavior. Epiphenomenalists simply reply that what has evolved here is nonconscious neural activity that causes both behavior and consciousness.[11] But Lindahl and Arhem (and others) respond that fully conscious brains use considerable energy, which would have prevented minds from evolving unless they actually produced behaviors with survival value. Another source of survival value is that minds may have helped steer nervous systems that have become too complex and unstable to steer themselves.

This is quite persuasive. Yet critics will inevitably feel that this dualism proliferates entities and posits obscure causality between them.[12] But most of these critics' own theories are certainly no less problematic. In the end, Lindahl and Arhem give a sophisticated, multi-layered defense of interactionist dualism that builds on the comparable views of Kohler, Libet, Eccles and Popper. This is a venerable, viable strategy for interactionist field theories.

3.3 Monist Field Theory

Unlike dualism, monism states that only one basic entity exists, although perhaps in different forms. McFadden (2002) offers a monist field theory based on dual-aspect theory, where the mental and physical are perspectives on an underlying entity. Here he adapts Chalmers' (1996, p. 305) view that "Experience is information from the inside; physics is information from the outside." However, these two perspectives just passively reflect information, which precludes mental-physical interaction and mental autonomy. Also information is an abstract relation (involving, e.g., alternative states, or correlations between senders and receivers). So how can it be privately experienced as pain and publicly observed as fields, for example?[13]

Pockett (2000) offers a monist field theory based on physicalism, in which consciousness is identified with certain EM field patterns. This faces the explanatory-gap argument (see below) against physicalism. This identity may also involve supervenience, which raises further issues of its own (Stoljar, 2015). Supervenience also precludes interactionist field theories, which would bother field theorists other than Pockett. The main point is that, despite the impressive strength of their neuroscience, Pockett and McFadden's monist theories aren't as strongly defended metaphysically as Lindahl and Arhem's dualism is.

But physicalist field theory can be formulated to avoid its issues, and thereby offer a defensible monist alternative to dualist field theory. Indeed, this physicalism arguably avoids all perennial mind-body problems (see Jones, forthcoming #1). To start with, Russell (1927, p. 320) said that we can't know what brains are really like behind our perceptions of them, so minds can conceivably be brains for all we know. This draws on Locke's view that we perceive the world indirectly by sensory organs, reflected light, etc. so we can't know its underlying reality behind these sensory appearances.[14] Skeptics can't reply that it's inconceivable for the brain's underlying reality to be conscious, for they lack ways to support this claim, as just noted.

This so-called "realist" view has been variously developed from Feigl to Strawson, but it can also underpin a physicalist, interactionist field theory (Jones, 2010, 2013). In this view, the mind literally is the brain's field, behind what is observed of the field by EEGs, etc. This is arguably why pains and visual images can't be seen in the brain. They're hidden behind what is observable of it. This realist field theory is physicalist in the longstanding sense that everything exists in physical space (yet not in the sense that physics covers all laws of behavior, we'll see).

If treating pains as fields sounds strange, consider how neural fields resemble pains and other sensory images. Both are arguably intangible and spread across space. Both arguably arise from grainy neural tissue in smooth, continuous forms. Additionally both are unified wholes, unlike discrete neurons. Sensory images are even isomorphic with electrical activity in neural maps. Also pain arguably makes us cringe and bristle in force-field-like ways. Of course, pains are privately experienced, while fields are publicly detectable. But pains can be hidden from public view behind what's perceivable of fields, and this makes pains and the hidden nature of fields private.

This realist field theory defuses the basic argument against physicalism, namely, that there's an explanatory gap between subjective qualities like pain and objective quantities like fields (or their quanta or information). The gap arises because pain isn't observable in these quantities, and can't be fully explained in terms of them. But this doesn't threaten the realist physicalism above. For the fact that pain isn't explicable by physics can't prevent pain from being the underlying nature of neural fields behind what physicists detect of them by EEGs. We can't access this hidden, underlying nature, so it may include pain for all we know. Similar tactics can defuse conceivability and knowledge arguments against physicalism (Chalmers, 1996; Stoljar, 2001; Jones, forthcoming #1).

Realist field theory can also avoid emergentism's issue of how experience can arise from what lacks experience. Instead everything has experience (panpsychism). Furthermore, EM fields bind minimal experiences in neurons into fully conscious minds. For example, these fields bind simple colors in visual detectors into fully conscious visual images in neural maps (for more details, see Jones, forthcoming #1-2). This view might become compatible in one way or another with monistic field theories like Pockett (2000), McFadden (2013), Fingelkurts et al. (2010, 2013), and Hales (2014). All might say that perturbations in neurons are reflected in field perturbations, and this field unites all this conscious activity into a fully conscious form behind appearances. Yet this doesn't address divisive issues that may separate these theories (see table 1 in Jones, 2013).

Realist field theory precludes epiphenomenalism, for minds are the underlying nature of fields that interact with brains. By contrast, dualist and dual-aspect field theories treat minds as products of nonconscious fields, which invites epiphenomenalist replies that minds emerge from the fields as epiphenomena. Treating minds as the underlying nature of fields blocks such replies. This also avoids dualist causal issues in other ways. It replaces any potential nonphysical causality with causality that occurs entirely in physical space, and it replaces the causal reductionism in §3.2 with causal realism. But the overriding point is that, despite their differences, dualist and realist field theories are allies that offer their own important arguments against epiphenomenalism.

Realist field theory also precludes supervenience physicalism, where minds don't change without corresponding neural change. Neuroscientists can detect fields shifting across the brain, but they can't explain how conscious fields weigh moral choices or even choose which foods taste best. These qualia comparisons occur in the fields' hidden, underlying nature. This brings subjective, qualitative dynamics to fields. Furthermore, these conscious fields *bind cognition into unified, effective forms* and help guide brain activity (§1.5, §3.1). So our behavior has conscious causes autonomous of physics.

This also counters influential manipulation arguments that we're just puppets of laws of nature beyond our control and thus lack free will (as self determination). Instead our actions are partly determined by subjective qualities of our consciousness working outside laws of physics.[15]

This autonomy helps distinguish us from other beings. Robots lack autonomy because they get their basic aims ultimately from us. But we get our basic aims from deliberating upon our values and feelings in conscious, subjective ways. This autonomous deliberation is more evident in us than other animals, partly due to our symbolic language (Jones, 1994, pp. 278ff.). It helped reconstruct our minds and societies into more rational, civilized forms. Actions became less dominated by perception and instinct, and more reflective and voluntary. We entered a world of ideas whose vast possibilities helped make us free and self-determined, instead of puppets of external factors beyond our control. But these possibilities also created our unique predicament. We lack both the steadfast instinctual guidance of other animals and the omniscience of gods (if they exist). We're left between them, in a uniquely human world of bewildering choices, intractable dilemmas and horrific conflicts. So our freedom is limited.

4. Conclusions

Based on mounting evidence, this paper has argued that minds are neuroelectromagnetic fields which interact with brains.

Evidence that minds are electromagnetic fields comes from research on how separate brain activities bind to form unified percepts and minds. Existing binding theories based on synchrony, convergence, and attention are problematic. Field theory explains the correlations and divergences between synchrony, attention, convergence, and unified minds, while avoiding the problems in other binding theories. This is good evidence that EM fields are what bind brain activities into a unified, conscious form. Both minds and fields have this unity, and the simplest explanation is that minds are fields. Also, treating minds as the underlying, intrinsic nature of these fields avoids the perennial problems in mind-body theories (by adapting ideas from Bertrand Russell). It's a particularly defensible field theory.

There's also mounting evidence from Frohlich and McCormick (2010), Anastassiou et al. (2011), Hales (2014), etc. that these fields interact with brains and help guide brain activity.

Epiphenomenalism, where minds lack causal powers, is precluded by this evidence that minds are fields that interact with brains. Supervenience physicalism, where no mental changes occur without corresponding neural changes, is precluded too. For neuroscientists can't fully explain the conscious fields' dynamics. They just observe fields shifting across brains – not how the fields weigh choices about morality. This occurs in the fields' hidden, underlying nature. It introduces subjective, qualitative dynamics to fields. Because these conscious fields bind our cognition into unified, effective forms and help guide brain activity, our behavior is partly autonomous of physics. Without this autonomy, we'd be puppets of natural laws beyond our control, which conflicts with interactionism's motivations.

Other field theories can also address binding problems and perennial mind-body problems, as well as epiphenomenalism and supervenience physicalism. Yet they may face residual issues. For example, theories that don't identify minds with fields can't preclude epiphenomenalism. For epiphenomenalists can simply argue that minds arise from fields as epiphenomena. Here again treating minds as the underlying nature of neural fields may be a particularly defensible theory.

Notes

1. For example, critics tried to falsify field theory by showing that animals can do visual tasks after their cortical currents are blocked. But these experiments utterly failed to verify that current disruption or field distortion actually occurred. See Jones (2013) for further examples.

2. Consciousness is our privately experienced inner life. We lose it in dreamless sleep.

3. Binding by attention can utilize different neural mechanisms, including synchrony.

4. A referee helpfully points out that this theoretical conceptualization is compatible with the brain operational architectonics (OA) framework centered around the notion of operation and proposed by Andrew and Alexander Fingelkurts (2001) and Fingelkurts et al. (2001, 2009, 2010, 2013). In short, the OA theory claims that local fields of transient functional neuronal assemblies are equivalent to elemental operations, and could reliably be measured by EEG in the form of quasi-stationary segments (Fingelkurts et al., 2010). In this sense different (simple) phenomenal features are presented in the brain by such local fields/operations generated by different transient neuronal assemblies, and temporal coupling of these local fields/operations produces complex brain operations responsible for complex phenomenal objects, concepts, gestalts, and intentional actions (Fingelkurts and Fingelkurts, 2001; Fingelkurts et al., 2009). Each of them is instantiated by the particular volumetric spatiotemporal pattern in the electromagnetic field (Fingelkurts et al., 2010). Thus, within the OA theoretical framework, any complex operation or operational act has internal structure where each element in its turn also has its own internal structure and so on, all the way down to the simplest elemental operations. Such architecture has a clear nested hierarchy and thus could serve as the needed ingredient of brain organization that allows conscious thoughts/images of different complexity to be expressed in the brain (Fingelkurts et al., 2013).

5. According to the Fingelkurts works already cited such EM fields produced by neuronal assemblies are consistently correlated with changes in the phenomenal-subjective content during both spontaneous (stimulus independent) and induced (stimulus dependent) experimental conditions (for the review see Fingelkurts et al., 2010, 2013). Moreover, it has been documented that the local fields of various neuronal assemblies correlate with different conscious percepts (Singer, 2001; Freeman, 2007; van Leeuwen, 2007) and if cognitive processing does not take place, such transient functional neuronal assemblies do not form (Pulvermueller et al., 1994). The reason we only see a camouflaged grasshopper after we focus attention on the object is that synchrony (which accompanies attention) creates a strong complex operational module within the brain field that binds several features of the attended object (shape, color, texture, etc.) presented by local EM fields into a unified, conscious percept – the particular volumetric spatial-temporal pattern in the electromagnetic field of the brain (Fingelkurts and Fingelkurts 2001; Fingelkurts, 2009, 2010, 2013).

6. According to Fingelkurts et al. (2010, 2013) such a field has a clear nested hierarchy that allows the conscious mind to be expressed, and allows it to present the multiple features of consciousness (Fingelkurts and Fingelkurts, 2012).

7. Epiphenomenalists also draw on Wegner's evidence that conscious intentions often go

astray. Yet this evidence hardly precludes that consciousness causes actions. Nor must actions involve conscious acts of willing to activate muscles – a view he attributes to opponents.

8. Since electromagnetism underpins the physics of brains, Hales feels that field theories of mind are credible (p. 353). His paper supports field theories like McFadden's (p. 315). Hales attributes the subjective colors, pains, etc. that we experience to virtual bosons ("qualeons") caused by channel fields interacting with the static electric field (pp. 350ff.).

9. "Physical" is typically defined as what's investigated by physics, or what follows the laws of physics, or what exists in space.

10. "INUS condition" refers to insufficient but necessary parts of a condition that is itself unnecessary but sufficient for their effects – as when lit matches aren't sufficient for forest fires, but are part of a constellation of conditions jointly sufficient for forest fires.

11. For example, epiphenomenalists can argue that nonconscious smell and taste mechanisms evolved to detect fresh and rotten food, and make us choose the former. Yet critics might still reply that this doesn't explain why we usually add lemon to tea instead of coffee, or pepper to steak instead of dessert. For these actions don't affect survival or evolve by natural selection. They're not based on these external factors, but just on consciously comparing tastes.

12. For example, the regularity account of causality above reduces causality to regular conjunctions of perceivable events in certain conditions. Arguably, this doesn't explain why the conjunctions exist (e.g., why currents regularly move compass needles). Causal realists avoid this obscurity by treating causes as forces (like EM) that underlie perceivable conjunctions (e.g., by pushing compass needles). Lindahl and Arhem (forthcoming, §3) feel that this view isn't verifiable and tends towards mind-body reductionism. But the causal realism in §3.3 avoids these criticisms. It replaces reductionism with Russellian realism. Also, while it isn't verifiable, it is justifiable as a Kantian regulative idea for making psychology coherent by avoiding perennial mind-body problems in monist and dualist theories.

13. Chalmers could reply that physics just describes the extrinsic, informational structure of things, not their essential, intrinsic nature (1996, pp. 304f.). The latter is conscious and grounds the former, thus giving substance to abstract information (Russellian monism). But how the concrete grounds the abstract is no clearer with Chalmers' information than with Plato forms.

14. This avoids the Russellian monism in the preceding footnote, for it doesn't treat matter-energy as abstract structure that needs grounding. Yet its "underlying realities" do somewhat resemble Russellian monism's "intrinsic natures", though the latter is dispensable.

15. The free will debate is too complex to fully address here. The point above is just that field theory can circumvent prominent arguments against free will. Another argument against free will is that if (as above) our choices determine our actions, then we're not really free to do otherwise than we actually do. But, in response, the early, spontaneous stages of many choices may be subtly affected by indeterministic quantum events that influence neuronal firing. Later stages are more deliberate, thus preserving self control over choices and some self determinism.

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