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Neuroelectrical Approaches To Binding Problems

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How do separate brain processes bind to form unified, conscious percepts? This is the perceptual binding problem, which straddles neuroscience and psychology. In fact, two problems exist here: (1) the easy problem of how neural processes are unified, and (2) the hard problem of how this yields unified perceptual consciousness. Binding theories face familiar troubles with (1) and they do not come to grips with (2). This paper argues that neuroelectrical (electromagnetic-field) approaches may help with both problems. Concerning the easy problem, standard accounts of neural binding by synchrony, attention, and convergence raise serious difficulties. These are avoided by neuroelectrical approaches in which the brain's field binds distributed processes in myriad neurons. Concerning the hard problem, binding theories do not squarely address how to get from neural unity to unified consciousness. This raises metaphysical difficulties involving reductions, emergence, etc. Neuroelectrical (and Russellian) approaches may help avoid these difficulties too. These approaches may thus deserve further investigation as binding theories.

Keywords: binding problem, combination problem, hard problem, panpsychism

Minds are characterized by their intelligence, which is their problem-solving ability, and by their consciousness, which is their privately experienced inner life of perceptions, emotions, and thoughts (this is lost in dreamless sleep). Consciousness has qualities (qualia) like pain and fear. Consciousness is private in that we cannot access each other's experiences. Consciousness also has unity, for example, the myriad shapes and colors in a visual image (and associated emotions and thoughts) are experienced as a unified whole. Consciousness also has causal characteristics, for example, it arises from brains and may affect brains.

For nearly a century, various neuroscientists have seated minds in neuroelectrical activity, primarily in electromagnetic (EM) fields. These EM fields arise mainly from electrical impulses in neurons that travel down axons via their membrane channels, then initiate synaptic signals to other neurons. The electrical impulses

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usually occur in bursts, causing oscillations whose frequencies are reflected in the fields. These fields resemble mental activity, for example, sensory images arguably arise from discrete neurons in field-like ways as unified wholes spread intangibly across space (Libet, 1993).

These neuroelectrical (or field) theories of mind have withstood various criticisms. For example, critics tried to falsify them by showing that animals can do visual tasks such as running mazes even after the cortical fields that create visual images are blocked. But, as later realized, maze learning involves many complex sensori-motor abilities. So, deprived of one ability, animals can learn mazes with other abilities. So the criticism is flawed. Field theorists also faced challenges in explaining, for example, why minds are not affected by fields outside brains, what keeps minds apart, whether just EM fields are conscious, and how our various qualia and images arise. However, they now offer various well-developed replies to these challenges (Jones, 2013).

Field theories have proliferated because they draw on considerable experimental evidence and offer ways of avoiding neuroscience's problems in explaining minds. One such problem is the binding (or unity) problem of "how we achieve the experience of a coherent world of integrated objects, and avoid seeing a world of disembodied or wrongly combined shapes, colors, motions, sizes, and distances" (Treisman, 1998, p. 1295). Similarly, for Singer (2007, p. 1657), the binding problem involves "how the computations occurring simultaneously in spatially segregated processing areas are coordinated and bound together to give rise to coherent percepts and actions." The binding problem further concerns how perception binds with thought to form an overall, unified experience.

Most neuroscientists attribute perceptual binding to synchronized firing by neurons, hierarchical convergence of neurons, or focal attention. But each raises issues. Field theories may help here. In doing so, they may align with Tononi's predictions of when consciousness appears in brains.

Finding a viable binding mechanism is part of the so-called "easy problem" of which neural processes (e.g., synchronized firing) correlate with consciousness (Chalmers, 1996). But the binding problem, as just characterized, also involves the "hard problem" of just how neural processes such as synchrony can actually yield conscious percepts. This hard problem raises perennial issues of dualism, reductionism, emergentism, panpsychism, etc. For example, does consciousness pop into existence fully formed? Or does it emerge by uniting simple conscious elements? Field theories may help with this too, if allied with (for example) recent Russellian theories of mind. The claim here is not that hard and easy problems are readily separable in practice, but just that they raise different issues that need to be addressed in separate ways.

Easy Binding Problems

Current Problems

One theory of neural binding is based on synchrony. Here the binding of simple sensory features like moving shapes involves spatially segregated neurons firing in synchronized lockstep — a temporal code for binding. For example, Gray, König, Engel, and Singer (1989) originally showed that neurons in cat primary visual cortex (V1) fire in phase in response to stimuli patterns moving together in coherent ways. Roelfsema, Engel, König, and Singer (1997) reported that in tasks requiring focused attention, synchrony appeared across various cortical areas with zero-time lag in awake cats. Synchrony has roles in feature binding, multi-sensory integration, attention, memory, etc. (Singer, 2007).

Yet this view is controversial. Thiele and Stoner (2003), Dong, Mihalas, Qiu, von der Heydt, and Niebur (2008), as well others, found that feature binding and synchrony do not correlate. Similarly, Hardcastle (1994) argues that while Gray and Singer's (1989) data showed that shape-responsive neurons synchronized, this data also showed that color and shape neurons actually failed to synchronize. Also, Koch, Massimini, Boly, and Tononi (2016) point out that synchrony occurs without consciousness during anesthesia and seizures. Here hypersynchrony arguably disintegrates binding.

Binding by synchrony also faces theoretical issues. One of many examples is found in Goldfarb and Treisman (2013). They note that binding by synchrony involves neurons firing in synchrony when these neurons encode separate features of the same object. Goldfarb and Treisman (p. 267) 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." Also, Prinz (2012) notes that if a perceived shape has both red and white areas, then color neurons will supposedly synchronize and bind not just with shape neurons, but also (oddly) with each other.

Another approach is binding by attention. Attention helps us interpret perceptions, and it is arguably tied to consciousness, as when we scan a crowd and suddenly become aware of a friend's face. 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."

But binding can occur without attention. Treisman (2003) showed that normal subjects experience illusory conjunctions if focal attention is thwarted. Importantly, LaRock (2007, p. 759) observes that these individuals "still performed the function of binding, albeit of an illusory conjunction sort." Simple features bound into a conscious, unified percept, without attention.

Another approach is binding by convergence. Here hierarchies of feature detectors converge on increasingly general detectors, thus binding simple features into an overall object (e.g., a face). For example, LaRock argues that while synchrony and/or attention disambiguate perception, binding actually occurs by convergence, often pre-attentively. He builds on Lamme's (2004) 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, as well as meaningful experiences tied to attention and global access.

LaRock plausibly attributes a central role in binding to the detectors in inferior temporal cortex. These detectors identify objects stored in memory and help bind lower detectors into a spatially organized unity. A problem is that countless objects are novel, which suggests that potentially infinite detectors exist for them.

Neuroelectrical Approaches

Field theories can avoid the problems specific to each binding theory above. But I will start with how field theories can also avoid three problems these binding theories often share. These three problems tend to arise because binding theories explain neural communication in terms of synaptic connections. Note that this latter point applies even to binding by synchrony, for Merker (2013) observes that binding by synchrony is registered only by its effects on synaptic connections, so this binding does not really differ from binding by convergence.

1. Zeki (1993, 2003) reports that the color and shape pathways are separate and parallel, and lack systematic synaptic connections. This raises the question of how the pathways can bind to form colored shapes in images. In field approaches, by contrast, electromagnetic fields can reach across pathways to pool information into a unified, conscious whole. This can occur, for example, in cortical maps where color and shape elements (for each point in an image) are nearby. The same applies to binding generally. Zeki (1993, p. 296) states, "there is no single cortical area to which all other cortical areas report exclusively, either in the visual or in any other system." But the brain's single field can bind these activities too.

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, since fields arise from fixed neuronal structures like intricate music from a fixed orchestra.

3. Synaptic accounts face difficulties in explaining smooth areas of color in images, for neurons, molecules, etc. are discrete and grainy. In contrast, strong fields are continuous versus grainy — their quanta form a unified probability cloud of continually high energy across space.

Field theories also avoid the specific problems in each of the binding approaches above. McFadden's (2013) field theory is crucial here. To start with, he argues that we are unaware of information in neurons until the brain's conscious EM field binds the information into a unified, conscious form (this addresses both the easy and hard problems). Synchrony just plays an indirect role by amplifying these fields (ibid., pp. 156f.). When neurons fire asynchronously, peaks and troughs in their oscillations are not in phase, so their fields often cancel out. But with synchronous firing, peaks and troughs reinforce each other to create a strong EM field oscillation (p. 157). The reason we only see a camouflaged grasshopper after we focus attention on its location 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 further here by showing that not only does synchrony reinforce fields, but in turn fields promote synchrony (ibid., pp. 162f.). Important experiments by Frolich and McCormick (2010) as well as Anastassiou, Perin, Markram, and Koch (2011) show that applying external fields to neurons can actually slow the neurons' electrical oscillations and make them synchronize. These fields thus help select which networks will synchronize: they can thus help shift the focus of attention. To summarize, fields help shift attention's focus by initiating synchrony in different neural networks, which in turn boosts the networks' fields and thereby binds their activity.

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

But McFadden does not delve much into how field theories can avoid the problems in other theories of binding. I will turn to this now. (The differences between field theories, including McFadden's and my own, are described in Jones, 2013.)

Field theories can avoid theoretical problems in binding by synchrony concerning which elements bind with others to create objects and overall scenes. Here they can explain perceptual binding in terms of fields in cortical maps (as above). 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 are not at full strength due to synchrony (e.g., when highly active color and shape pathways are nearby in cortical maps). Also, synchrony occurs without binding during anesthesia and seizures. This synchrony (hypersynchrony) likely overloads sensory circuits and stymies feedbacks that gate processing beyond its earliest stages. But binding can correlate with fields here. For fields cannot effectively bind sensory features together when feedbacks for color constancy, perceptual grouping, etc. are stymied. This latter point aligns with Tononi's account (in Koch et al., 2016) of where consciousness appears in brains (further alignments will appear in the five "binding factors" below).

Field theories can also avoid the problems in binding by attention. To fit the evidence above of pre-attentive binding, three binding levels are needed. (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 form.

Field theories can likewise avoid the problem in binding by convergence. Field theories do not require infinite top-level detectors to bind information into conscious, unified objects. Binding into colored shapes can be achieved (as just noted) by fields in neural maps pre-attentively. Top detectors just help recognize some of these shapes as meaningful.

In these ways, neuroelectromagnetic fields can bind cognition into a unified form, and minds can be seated in these fields. Both points work together above to explain the correlations and divergences between synchrony, attention, convergence, and unified consciousness, while avoiding the issues in other binding theories. Field approaches thus offer ways to deal with the easy problem of neural unity, while also initially addressing the hard problem of consciousness, to which I will now turn.

Hard Binding Problems

Current Problems

The hard binding problem concerns how the neural unity above actually yields unified consciousness. This involves reductionist, dualist and other issues in explaining consciousness itself, as well as emergence issues in explaining where the unity of this consciousness comes from. These hard problems arise because standard theories of consciousness are hard to prove or refute, and hard to fully defend against critics who view them as fatally flawed. The theories are thus deadlocked.

So, in explaining consciousness itself, how can field theorists spell out their vague claim that minds are seated in neural fields? One option is to adopt a standard theory of consciousness and defuse its problems. Here Lindahl and Arhem (1994) offer sophisticated defenses of dualist field theory. Other field theorists have adopted dual-aspect theory (McFadden, 2002) or identity theory (Pockett, 2000), but without fully defending these monist views. A second option appears below. It tries to refine field theory along Russellian lines to avoid dualist and monist issues. This theory serves as a Kantian-like regulative idea (1787/1965, b706-710) which is not provable or verifiable, yet tries in pragmatic ways to make psychology coherent by avoiding hard issues.

Russellian Approaches

Realists have long argued that we just perceive the world indirectly by sensory organs, reflected light, etc. so we cannot know the world's real nature behind these sensory appearances. Bertrand Russell (1927/1954, p. 320) added that we cannot know what brains are really like behind perceptions of them, so minds can conceivably reside in brains behind appearances. This idea, which has been variously refined from Feigl to Strawson, may yield a field theory that avoids hard issues.

This realist field theory modifies the field approach described above by treating neural fields as conscious behind what is observable of them via EEGs, eyes, etc. For example, pains literally exist in these fields and exert forces that EEGs detect. Similarly, visual images exist in visual circuits, hidden behind what we see of circuits via our eyes and reflected light. Physicists cannot object here, for they just describe fields by their potential effects on charges, so the fields' underlying nature (what actually exerts the forces) is up for grabs. Skeptics who say that this reality cannot conceivably be conscious therefore lack ways to support their claim.

If this theory sounds strange, consider how neural fields resemble pains and other sensory images. Both are intangible and spread across space. Both arguably arise from grainy neural tissue in smooth, continuous form. 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 detected. But pains can be hidden from public view behind what is perceived of fields, which makes these hidden events necessarily private. (Pains can also be private in that fields are too weak between our brains to unite our experiences together.)

I will now turn to whether this realist field theory does in fact avoid the issues in other theories of consciousness. The aim will not be to debate the issues. The aim will just be to briefly list the issues to see if they are avoidable.

To start with, reductive physicalism explains consciousness in more basic terms of neuroscience. Critics say that this faces an explanatory gap between subjective qualities like pain and objective quantities like neural processing.

Pain is not observable in these quantities and is not fully explained by them. So arguably pain is not physical. (The phenomenal-concept strategy offers replies, yet its claim that future science will explain pain raises its own familiar issues.)

Realist field theory avoids this issue. Even if neural processing cannot fully explain pain, pain can still be the underlying physical nature of neural fields behind what EEGs detect. For we cannot access this hidden, underlying nature, so it may include pain, for all we know. (Chalmers, 2003 and Stoljar, 2001 use similar tactics to defuse parallel conceivability and knowledge arguments against reductionism.) This physicalism is not reductionist, for pain is not identified with neuroscience's observable entities, nor is it explained in terms of anything more basic.

Many physicalists attribute pain not just to processing by one type of hardware, as in reductionism, but to processing by multiple hardwares, including inorganic ones. Pain is treated as token identical to the organization of this processing. But this organization comes and goes in pain circuits, so pain ends up popping in and out of existence from nonconscious circuits. To critics, this seems like magic.

Alternatively, this organization can be abstracted from circuits as a formal input–output structure. Here pain is not identical to circuit activities. Instead it is realized in them, like abstract computations are realized in computer circuits. But claims that abstract organization is realized in circuits seem no less obscure than Plato's claim that abstract forms are present in matter. The idea of pain being realized in circuits is often used to flesh out the formal claim that pain supervenes on circuit activities (where pain does not change unless circuit activities change). But supervenience raises its own additional issues of overdetermination, necessary beings, etc.

Realist field theory tries to avoid these various issues. They arise from positing three entities — pains, hardwares, and organizations — with difficult relations between each. In the field theory pains are instead simply hidden in fields behind appearances (a type identity).

In traditional dualism, minds are immaterial and nonspatial, yet interact with bodies. Critics reply that such minds cannot move bodies. They also reply that all physical events have physical causes (causal closure). Some dualists thus resort to epiphenomenalism, where brain events cause experiences, but experiences do not cause brain events. Critics feel that this view is manifestly false, though its weakest point may be its emergentism, where experience pops into existence from what lacks experience. Other dualists reduce causality to regular successions of perceivable events, whether material or immaterial. Critics feel that this leaves the successions inexplicable. Some "dualists" treat minds and bodies as dual aspects of an underlying entity. Critics say that this just shifts causal issues to this mysterious third entity.

Realist field theory avoids these causal issues, for its conscious fields are physical in the longstanding sense that they exist in space. Also, epiphenomenalism is avoided because neural fields interact with brains. Nor is causality reduced to mere successions of perceivable events — instead causes are forces that underlie perceived successions and actually explain their existence.

It may seem that realist field theory actually ends up smuggling in a dualism of hidden–accessible aspects or perspectives (cf. Chalmers, 1996, p. 136). In reply, no radical dualism exists here, for all perspectives are in physical space in this field theory: my neural EM field creates a unified consciousness whose qualia I can directly access; yet this field is too weak to unify consciousness between brains, so other people's qualia are hidden from me. This is not dualism, but physicalism in the longest-standing sense.

In idealism, bodies just exist as perceptions in the mind or spirit. Critics ask why we see an outer world that is not really there, and why minds seem so tightly tied to the brains we see. Idealists can attribute all this to spiritual causes, but not everyone accepts the spiritual. Realist field theory avoids these issues, for everything exists in physical space — which is physicalism, not idealism. Also, bodies exist beyond our perceptions of them, and minds exist in brains.

In neutral monism, minds and bodies are constructed from elements that are neither mental nor physical, but neutral in character. But if the elements are non-mental, this faces the issue of how minds can be constructed from them. If the elements are instead mental, this becomes idealism. Realist field theory avoids this neutral entity and its issues.

In Russellian monism, physics only describes the mathematical structure of the world, not the world's intrinsic nature. This intrinsic nature is experiential and grounds the world's mathematical structure, thus giving substance to the abstract structure. This monism takes many forms, including some theories already mentioned. It also inherits some of their issues. Realist field theory avoids these issues. Also, it makes no use of Russellian monist ideas of grounding (which again invokes Platonic obscurity). Instead it is Russellian in that consciousness resides in brains behind what we observe of them.

Informational accounts of consciousness raise some of the issues above, and new ones too. For example, information is an objective, abstract relation involving (e.g.) alternative states in a network or correlations between senders and receivers. By contrast, pains and other forms of consciousness are subjective, concrete qualities we feel. So it is hard to grasp reductive claims that pain is information. If the claim is instead that consciousness emerges from information, then it is hard to see how consciousness can pop into existence from what is not conscious. Russellian monists may claim that physics describes the world in extrinsic, informational terms, and that the world's intrinsic nature is conscious, which grounds information in something substantial. But grounding is obscure too. Realist field theory avoids these issues by not tying consciousness to information.

So, field theories can arguably explain consciousness. One way they can do so is by strongly defending standard theories (such as dualism) against criticisms. Another way they can do so is by avoiding these various criticisms by drawing on Russellian ideas. The remainder of this paper will focus primarily on this latter approach — realist field theory — because it is relatively new.

Neuroelectrical Approaches

I have been addressing the hard binding problem of how neural unity yields unified consciousness. This involved looking at how field theory might explain consciousness itself in Russellian terms. I will continue with the hard binding problem by looking at how field theory might help explain the unity of this consciousness in neuroelectrical terms. Two further theories of consciousness, not fully addressed above, are particularly relevant here. I will turn to them now.

One explanation of this unity is emergentism. Here experience arises fully formed and unified from a nonexperiential mechanism (e.g., synchrony) in ways inexplicable by physics. But Strawson (2006a) replies that while life forms can intelligibly emerge in virtue of self-replicating powers in molecules, this "in-virtue of" relation is lacking if experience pops into existence from what lacks experience. The latter is unintelligible magic . . . where anything goes. (This same reply applies to panprotopsychist accounts of emergence too.)

The leading alternative explanation is panpsychism, which Strawson endorses. Here all things have mental qualities like experience or sentience, and unified experience emerges from simpler experience. But this has its own emergence issue in explaining how minimally conscious microexperiences in neurons unite to form macroexperiences (images, thoughts, etc.) and the subjects who apprehend them. According to James (1890), just as a statue is an aggregation of separate atoms with no inherent collective unity, so separate experiences are shut in their own skin in windowless ways, with no more collective unity than separate minds. So, experiences are inviolable, they keep their original identities and cannot intelligibly fuse together any more than minds can. This "combination problem" in panpsychism is a form of the binding problem.

Yet there are good reasons for instead holding that experiences can actually combine. To start with, Itay Shani (2010) replies to James that fusion does actually occur in nature. For example, hydrogen and oxygen atoms fuse electrically to form water molecules with new, unified identities that have polarity and can dissolve salts. So combination is intelligible. Shani intriguingly mentions a possible panpsychist "mental chemistry" akin to integrated living systems. Similarly, Dempsey and Shani (2009) treat consciousness (construed in Feiglian terms) as efficacious in self-organizing cognitive systems, which counters epiphenomenalism.

This is where field theories can help, for fields not only bind atoms into molecules, but also bind neural activity into unified, conscious forms. While most field theories adopt emergentism, realist field theory adopts panpsychism, and offers ways of defusing its combination problem. Here everything is minimally conscious behind appearances, yet microexperiences in neural circuits are united by fields to form intelligent, fully conscious minds. In this field theory of mind, minds arise in neural fields, yet are rooted in neurons.

So the combination problem may not be as intractable as the above list of deep metaphysical issues in theories of consciousness. The issues raised by the combination problem may be relatively more tractable, empirical ones about how fields unite microexperiences into macroexperiences, as we will see.

However, it might be objected that even if experiences can intelligibly combine, the subjects that own them cannot intelligibly combine. That is, arguably (1) all experiences have subjects that apprehend or own them, and (2) subjects cannot combine (e.g., Goff, 2009). But assumption (2), that subjects cannot combine, is dubious. Connected brains can be mutually conscious. For example, the conjoined brains of Tatiana and Krista Hogan share some sensory experiences. Conceivably, connections between prefrontal areas might allow two subjects to coordinate thoughts and integrate decisions. With other connections, one subject might control others by manipulating memories, attitudes, etc. Subjects might thus fuse to varying degrees.

Many philosophers, including Humeans, neutral monists, and Buddhists, also reject (1), that all experiences have subjects. Furthermore, it is hard to find any supporting arguments for (1). It may just be a hasty generalization from human experience. At any rate, it faces a serious empirical challenge. In the semi-stupor of fatigue, attention and thought are turned off, and objects are just blankly stared at. Experience of colored shapes still exists, for consciousness is not lost altogether. But there is no evidence for a subject who apprehends these experiences.[1] Thus, experiences can arguably exist without subjects.[2]

So, panpsychists can reply to (1) that microexperiences may intelligibly exist without subjects. But there still remains the question of just how macroexperiences

[1]Note that this argument against (1) addresses psychological subjects who apprehend (recognize, evaluate, etc.) their experience. Now, other subjects arguably exist that just own their experience, instead of actually apprehending it. Examples are Strawson's (2006b, pp. 191f.) "thin subjects" that are indistinguishable from their experiences and Zahavi's (2005) tacit self awareness. But note that these minimal subjects do not thwart my aim of defending combination in panpsychism. Instead they offer an alternative way to show this. For it is hard to prove minimal subjects cannot combine. After all, they are indistinguishable from their experiences, and experiences can intelligibly combine (as already argued). Generally, it is hard to prove that subjects cannot combine if they simply own experiences, or in one way or another lack introspectable psychological features of their own.

[2]Goff (2009), actually assumes both (1) and (2) above. Goff argues that a special kind of zombie could conceivably exist that has microexperiences with microsubjects, while lacking a macrosubject. Panpsychist claims that microevents combine to form macroevents thus seem suspect. But as Coleman (2012) notes, Goff assumes that microexperiences have subjects, and subjects cannot combine. This is what enables Goff to argue that it is conceivable for zombies to lack macrosubjects. Yet, as already noted, it is hard to prove that experiences must have subjects. In fact, Coleman argues that some combination mechanisms can conceivably unite microexperiences that lack subjects, so as to form macroexperiences with subjects. Moreover, this cannot occur without the macrosubjects coming into existence. Goff's panpsychist zombies are therefore not conceivable, and his argument fails.

with subjects can emerge from microexperiences without subjects. This will be addressed below.

The realist field theory described above shares the realist physicalism that Feigl and Strawson tended toward. While these authors did not adopt field theory, they may have profited from it. Feigl said little about emergence. Strawson ignores how qualia emerge, and his thin subjects are irrelevant to how actual psychological subjects emerge. Field theory offers ready ways of dealing with these issues. So, it can arguably do what Feigl and Strawson do not do: avoid perennial mind–body problems instead of just switching one problem for another.

Examples of Binding

Binding in Perception

The preceding argument was that hard problems concerning consciousness and its unity can be avoided by realist field theory cast in a panpsychist form. But, as already noted, one issue needs further attention. How do macroexperiences — perceptions, emotions, and thoughts — and their subjects emerge by binding microexperiences together? I will start with how perceptions emerge.

All accounts of how brains create conscious perceptions are speculative, but the realist field theory below fits current evidence. It also explains perception without the issues found in standard approaches. The latter do not fully explain how sensory images get pictorial shapes (given that higher detectors cannot spot all possible shapes), nor how color and shape processing bind, nor how neuronal processing yields conscious images. But realist field theory offers ways of avoiding these and other issues involved in perception.

In this panpsychist field theory, all atoms have minimal microexperiences, yet the brain's field unifies microexperiences in neurons into a fully conscious form. This field is a continuous, unified whole, unlike discrete neurons and molecules, so it is most likely the only thing in brains that can pool microexperiences into a single, fully conscious percept. In the brain's electrical circuitry, this continuous field exchanges energy between ions, forming a continuous, conscious unity between their microexperiences (while these circuits have synaptic gaps, this does not block the continuity of electrical activity, for extracellular currents spread all along the circuits). In strong fields, quanta form a unified probability cloud of continually high energy across space. But as this flux density dissipates, field continuity and conscious unity deteriorate.

The underlying nature of the energy field is conscious in this theory. This differs from other field theories. It is not information in fields that is conscious, but the energy in fields. Fields are thus most conscious where they are most energetic. That is, fields are not fully conscious globally across the brain, but just locally along the currents of the circuits that create them. These energetic fields fully unify consciousness. That is, they are fully conscious.[3]

These localized fields generate intense, unified experience in various kinds of circuitry. (1) This experience arises in highly interconnected circuitry (lesions interfere with this). Here a continuous field throughout the circuitry unites various networks of conscious activities. This occurs in the hierarchical and local connections of cortex, but less so in cortical appendages where activities occur separately in parallel. (2) Intense, unified experiences often arise in circuits firing synchronously, as already explained. (3) Intense, unified experience of pain, color, etc. arises as many neurons fire rapidly (and it wanes as few neurons fire slowly). Here ions move continuously in and out of many adjacent neurons, so a strong EM field continually exists. This temporal continuity breaks down when circuits fire in pauses and bursts during seizures, NREM sleep, and anesthesia. (4) Intense, unified experience arises in circuits with densely packed neurons in tight alignment, as in cortical columns. Here conscious EM energy is highly concentrated. (5) This experience arises in extensive cortical feedback loops, which increase lower-level activity (including its synchrony) and facilitate higher-level attentive activity.

These five binding factors fit evidence that we are usually most conscious when circuits are highly active, highly connected, synchronized, and/or engaged in cortical feedbacks (Jones, 2010, 2013). These factors often align with Tononi's use of neural integration and differentiation to predict when consciousness appears. Without some of these factors, unified experience will arguably dissolve into isolated, subliminal microexperiences. These factors may thus be essential to intelligent, fully conscious minds.

My account of perceptual binding will focus on visual images. To start with, how do these images get their colors? While research into the fine molecular structure of sensory neurons has just begun, there is growing evidence that detectors for pain, taste, sound, etc. respond to stimuli via highly specialized molecules (Jones, 2010). For example, special molecules detect sweet, sour, bitter, and savory tastes (Oike et al., 2007), while other molecules detect various degrees of burning pain (Basu and Pramod, 2005). As realist field theory predicts, the molecules reside in the most electrically active sites of detectors (ion channels) where fields are strongest. Such research may eventually help to empirically decide between the panpsychist, type-identity approach above and approaches involving token identity, multiple realization etc.

Research into these molecules has focused on peripheral detectors (the detailed molecular structures of channels in higher detectors is not yet known).

[3]The localized nature of these strong fields along brain circuits offers one explanation for why consciousness is unified within each brain, but not between brains. This justifies calling these strong fields "localized" even though there is actually only one universal EM field. This addresses the so-called "boundary problem" of how and where microexperiences are corralled into units.

Different qualia could reside in the molecules' different quarks and leptons, or in their strings. Strings vibrate in many dimensions, so they can harbor many qualia. Different qualia could also plausibly reside in the different rest energies of atoms and molecules which are unified by intense fields.[4] (Yet some field theories instead attribute qualia to larger-scale energy patterns across fields.) One way or the other, a handful of these primary qualia can combine to form thousands of secondary qualia.

Primary colors are thus attributed to the underlying nature of these specialized molecules in wave-length detectors. These detectors can be found in (for example) the so-called "globs" of V4. Each glob is a dense cluster of myriad color-detector cells that respond to all light wavelengths. But when a short wavelength enters the eye, the strongest response in globs is from cells where blue qualia predominate. The localized field along visual circuits connects these globs into neural maps, thus forming colored areas in images. These colors are not observable in brains, for they reside there behind appearances (as already explained).

Secondary colors arise by fusing these primary ones. If blue and green connect to the same map location, they pool together and thereby blend in the field to form turquoise. This can explain well-known evidence that when a disk with two colors spins, we see the colors blend into an intermediate color. These two colors come from glob cells that connect systematically across neural maps. These colors thus fuse at each point across images.

In dualist field theory, where qualia differ from neuroelectrical activity, this fusion is not easily explained. But, in realist field theory, qualia are the underlying nature of neuroelectrical activity, and the continuity of the brain's field is the continuity of the field's underlying consciousness. So, qualia pool and fuse in this field in understandable ways (cf. Coleman [2012] on combination via entanglement). This explanation is not mere analogy: consciousness and its unity literally exist as fields (this is what avoided perennial mind–body issues above).

This addresses the so-called "palette problem" of how a few microqualia combine to form myriad macroqualia, for several primary colors can fuse to create many secondary colors (e.g., turquoise). Their intensities can also fuse. Many highly active detectors create intense colors, while fewer weakly active detectors create faint colors. If the primary colors are unmixed with other hues, the saturation of the secondary colors is high, otherwise it is low.

How do these visual images get their pictorial form? This raises the so-called "structure problem" of how the combining of microexperiences creates structures in macroexperiences. In most field theories it is unclear where the pictorial, spatial structure in images comes from, for the spatial patterns in fields are used instead to

[4]But note that these correlations of strings/qualia, etc. cannot be explained any more than charge/particle correlations in physics — even so, these are not serious explanatory gaps, for we just lack cosmologies today to explain them.

explain the various colors in images. But in realist field theory, pictorial images can arise from the spatial structure of retinas or cortical maps.

I will start with how retinas might help create our pictorial images. The point is not that our images actually reside in retinas, for retinas are too crude to account for the complexity of our images. Nor is it clear that retinas can be fully, versus subliminally, conscious. For retinas have dense arrays of interconnected and rapidly firing cells, yet they lack access to reentrant connections from cortex (recall the five factors above).

Still, retinal activity does have a pictorial form that is isomorphic with our visual images. This isomorphism includes the elliptically shaped peripheries of retinas and images. Also, images are warped by retinal detachments and warping. Furthermore, the retina's interconnected cells give it unified consciousness, and it connects systematically into higher detectors. So, even if the retina is just subliminally conscious, this systematic connection of higher detectors into retinas can unite all these detectors to form a fully conscious pictorial image.

For example, myriad V1 blobs connect tightly together into the retina's center, making the center of images pictorially detailed and smooth. But far fewer blobs connect into the retina's periphery, leaving peripheral images coarse, grainy, and crude. (This, along with the continuity of fields, addresses the so-called "grain problem" of how discrete neurons yield smooth areas of color in images.) V4 globs connect into these V1 blobs, giving full color to pictorial details in images. The circuits for color, shape, and motion are all ultimately rooted in the retina, which binds them into a smooth, pictorial form.[5]

This is how retinas can help create the pictorial form in images. But, as already noted, this pictorial form could also come from cortical maps. The difficulty here is that cortical maps are distorted relative to the images we experience. For example, V1 is the most detailed map and its activity is pictorial. But, relative to images, V1 is (1) split in half in separate hemispheres, (2) deeply folded, (3) expanded at its center, and (4) grainy in texture. Arguably, these distortions do not appear in images for several reasons.

(1) V1's halves are connected all along V1's midline by callosal fibers. Each fiber is too insubstantial to appear in images. Yet all these fibers together unite blobs from the different hemispheres into a single consciousness. We are thus aware of a unified image, but not any connecting fibers. The fibers knit the split hemispheres into a seamless image. (2) As these callosal fibers illustrate, the image's pictorial form is determined by how detectors interconnect. But these interconnections are not affected by cortical folding, so folding does not appear in images. (3) The reason that V1's central expansion does not appear in images is that V1

[5]Unlike their flat lines and colors, images also have depth. This depth is less perceptual than conceptual, for it is constructed from motor manipulations, etc. Other mechanisms behind the scenes bring contrast, constancy, object recognition, etc. to images.

is hierarchically connected into higher maps. This assembles increasingly complex patterns in images. These connections are dense at V1's center, but not at its periphery. So, numerous detectors at V1's center feed into relatively few higher detectors. This packs fine details — minus the expansion — into the image's center. (4) This packing of fine details at the center of images makes images smooth, while their peripheries remain gappy and grainy.

So, in realist field theory, unified images can arise from a single field running continuously along neural circuitries within the visual cortex — or between this cortex and retinas. Either way, images reside in our heads in realist field theory. This offers an alternative to images emerging from nonpictorial field information, as in most field theories.[6] Field theories therefore offer various ways of explaining images. Finally, note that realist field theory's predictions above concerning shapes, colors, and binding factors in images are often testable.

Binding at Higher Levels

Binding occurs beyond perceptual levels to yield emotions, thoughts, and the unified mind. To start with, the preceding approach to perception also helps explain emotion. There is some evidence that emotional qualia correlate with specialized molecules, just as sensory qualia do. These molecules reside in the electrical currents of hormonal receptors in limbic circuitry. This circuitry (the limbic cortex, amygdala, etc.) is rich in receptors for hormones such as steroids for sex, opiates for euphoria, and peptides for hunger and thirst (e.g., Pert and Snyder, 1973). These receptors may detect specific hormones using specialized ion channels (though evidence here is not as extensive yet as with the sensory qualia above). The field in neural circuitry could unify these molecular activities into our fully conscious emotions, and fuse them with our thoughts. (Note that these emotions are directed at objects and exhibit oppositions such as love/hate — Strawson [2006b] compares emotions to the forces and charges in physics.)

Realist field theory may also help explain thought, itself. We think with images that arise in the same areas used to create and inspect sensory images (Kosslyn, 1994). So, the field theory of images above helps explain thinking with images. We also think with abstract symbols. Yet this symbolic language is initially learned by referring to images (i.e., concrete objects), and it is afterwards used largely in automatic, subliminal ways. In contrast, thinking with images is fully conscious. It is this fully conscious thought that field theories of mind are designed to explain.

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[6]Realist field theory avoids the issue here of how conscious, pictorial images emerge from nonpictorial field information. For the images are instead simply hidden in neuroelectrical activity behind what EEGs show of it. This account of images as inner pictures in our heads does not commit the fallacy of positing a little man in an inner theater who makes sense of incoming images, for in this theory images are already conscious and meaningful. No homunculus is needed to make sense of them.

Thought occurs largely in prefrontal cortex, which connects into areas for emotion and lower cognition. This cortex has various areas used for working memories, which draw on lower areas. But there is no evidence of a unifying circuitry centralized in prefrontal cortex that all brain areas and all working memories feed into — any more than there is evidence of a central, unifying circuitry in visual cortex that all visual areas feed into (Zeki, 1993). So, the final binding problem concerns how different areas for perception, memory, emotion, etc. combine to give the mind its unified, conscious direction — which we attribute to the will or subject.

In realist field theory, this unified direction comes not from any central, unified circuitry, but from the brain's single, unifying field which arises from various interconnected circuitries. This field pools images from sensory areas, emotions from limbic areas, and thoughts from prefrontal areas. Many well-connected prefrontal circuits promote this unified experience. But it resides in the entire field, not in any central circuitry that all areas and working memories feed into.

In this unified, conscious field, our perceptions, emotions, thoughts, etc. combine and fuse synergistically (Jones, 1995). For example, in this field, emotion drives thought to solve problems. Thought then manipulates images and concepts, intuitively grasps relations (insight), reflects on alternatives, and ultimately makes decisions (volition). As this conscious energy field initiates tasks like remembering and imagining, conscious energy triggers (via reentrant loops) voltage-gated channels in neurons to control these tasks (recall the discussion of Anastassiou et al. [2011]). Levels of electrical activity (and thus consciousness) are thereby modulated in these networks. Via these voltage-gated channels, thought controls and trains neural networks, thus forging its own skills.

The mind's conscious direction comes from this synergistic fusion of perception, memory, emotion, and thought — all working together in a conscious energy field to do what they cannot do apart. This yields the plans, values, and memories that knit self identities into persistent forms. The self-aware subject (the will) can thus ultimately emerge — in ways detailed in the preceding pages — from simple microexperiences that lack subjects.[7] This addresses the final binding problem of how subjects emerge. This overall process of synergistic fusions partly parallels the integrated-systems approach in Shani (2010) and Dempsey and Shani (2009).

Neural imaging shows this conscious energy field shifting across the brain, but it does not show how the field weighs moral situations or even chooses which foods taste best. Such choices occur in the field behind appearances, and they

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[7] Arguably, minds lack these subjects or directors — instead different activities just compete for overall control. Yet, while this may explain spontaneous thoughts, it is hard to fully explain sustained, systematic deliberations thusly. Hume denied that any director or self exists, for it is not observable introspectively. But arguably it is observable in the form of the mind's decision making, which involves plans, values, and memories. This controlling center gives the mind's contents a continuous, coherent identity (Whiteley, 1973).

transcend the field's electrodynamic principles. Since these choices are based on directly comparing conscious qualities and directly intuiting conceptual relations, they introduce qualitative dynamics that go partly beyond physics. And since they are hidden activities, they are inaccessible to physics. This inner life of feelings, ideas, and plans exists in the energy field, where it controls motor circuits by exerting conscious electromagnetic forces. This aligns with the evidence above that this conscious field helps guide attentive neural processes, while binding cognitive activities into unified, effective forms.

This emergent dynamics avoids epiphenomenalism (cf. Dempsey and Shani, 2009). It also avoids supervenience and manipulation arguments against free will (a future topic). It differs from emergentism in that experience in itself does not emerge (as already explained), even though experience has emergent causality. Yet this does not conflict with the physical being causally closed, in the longstanding sense of "physical" where all events occur in physical space. But there is conflict with causal closure in that mental causality is not fully explained by physics.

Conclusions

The easy binding problem concerns how neural processes are unified. Neuroelectrical views attribute this binding to the brain's field unifying myriad neuronal activities. This avoids the problems in standard theories of binding, which is good evidence for neuroelectrical views.

The hard binding problem concerns how this neural unity yields unified consciousness. The perennial problems in standard theories of consciousness (reductionist, etc.) may be avoided in Russellian ways. Here, our consciousness resides in our brains behind what is observable of them. Problems with how this consciousness is unified can be avoided neuroelectrically by fields uniting microexperiences in neurons into fully conscious forms, such as pictorial images. There is no intractable unity or combination problem here, for fields can just as readily unify neural microexperiences (for the hard problem) as they can bind neural activities (for the easy problem). Other good neuroelectrical options exist, but this one arguably avoids perennial hard problems.

In the end, neuroelectrical accounts seem to fit current evidence while avoiding serious problems in standard accounts of how colors and shapes are processed, how they bind together, and how all this yields unified consciousness. So, neuroelectrical accounts may offer viable alternatives to standard approaches with their hard and easy problems. These neuroelectrical accounts may thus deserve further investigation.

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