Special Issue

Mind, consciousness and time: an integrated overview

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Abstract

The I suggest here that 'mind' can usefully be viewed as a process of integrating environmental dynamics with brain dynamics. It is probably expressed in brains in fractal patterns of ionic fluxes, especially calcium ion fluxes. Consciousness may be founded in a neutral monism at the basis of reality. As manifest in us however, it could prove to be a translation, mediated by implications of Heisenberg time/energy uncertainty, of spatio-temporal aspects of 'mind' into a tempero-spatial format. Differences between qualia might conceivably have a basis in knot theory. Potentially useful research directions are then briefly described.

Key Words:

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"[conscious] mind . . . is simply the intrinsic temporality of a physical event"
Alfred North Whitehead

Introduction

It's been a privilege over the past 20 years to have been asked to look at some 2000 or more papers on consciousness-related topics, often while helping out with *Journal of Consciousness Studies* editorial functions. All of these papers, whether subsequently published or not, have been instructive in one way or another although I confess that a very few have reminded me of the earl of Chesterfield's advice to his son (written *circa* 1750); "There is no opinion so foolish but ye may find somewhere a Professor who will defend it to the death."

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I thank the editors of this special issue for the opportunity to describe my own notions, which relate to the main theme of their recent book *The Unity of Mind, Brain and World*. (Pereira and Lehmann, 2013). My views have grown out of the rich soil provided by very many thoughtful writers and researchers, including other contributors to this issue. Any foolishness attributable to my suggestions or their expression is, however, entirely my own responsibility.

The picture underlying the ideas that I shall describe about conscious mind is similar to, but not quite the same as, Bernard Baars' (1997) spotlight metaphor. Whereas he imagined consciousness as 'lighting up' those aspects of mind involved in his 'global workspace', I see it as beaming out from aspects of mind that are partially describable in global

workspace terminology, albeit ones with a very different neural and physical basis from that envisaged by Baars.

Given a notion like this, there are many obvious questions to ask. Those that I shall tackle in this paper are nothing if not ambitious – perhaps too ambitious considering the degree of contemporary uncertainty or downright ignorance over so many relevant issues. All the same, 'nothing ventured, nothing gained'.

The questions are: How best to conceive of 'mind'? What form does the neural instantiation of mind take? How might consciousness arise and how could it relate to mind and neurology? Which lines of investigation may throw most light on these various conjectures?

Picturing 'mind'

Mind can usefully be regarded as a process (certainly not a 'thing') in the course of which complex entities assign meanings to incoming information on the basis of other information that is already stored within them, with outcomes that depend both on the nature of the assignations of meaning and that of the new information.

This is a rather general definition of 'mind' which allows its attribution to computers (information stored in their design and programs), trees (information in their genetics and developmental histories) and even to Gaia, or at least the biosphere as a whole. However, the status of computers is ambiguous because they are often better regarded as tools that are extensions of our own minds, lacking an independent mentality of their own, while the 'mentality' of organisms lacking brains is likely to be either so simple or so slow as to elude recognition. People harbour unusually complex examples of mind because of the complexity of their developmental histories and especially because so much of the stored information determining assignment of meaning derives from socio-cultural contexts.

An immediate implication of the definition is that 'mind' is not confined to brains. It's a dynamic process encompassing brains (in the case of animals and people), the bodies that harbour them and the environments with which they interact, especially the socio-cultural environments in the case of people. Edwin Hutchins (1996) for example showed in detail that, when people are navigating ships, much of the computational work attributable to their 'minds' goes on in culturally determined procedures and the artifacts that they use, not in their individual brains.

The picture of 'extended mind' that is currently gaining popularity among philosophers and cognitive psychologists (Clark, 2011) is a direct consequence of regarding 'mind' as a dynamic process involving brains along with their environments. It's no more than a natural extension of the 'embodied mind' movement (Varela, 1993) that attracted so much interest and support in the 1990s.

One can even make a somewhat tongue-in-cheek guess at a proportionate assignment to brain versus environment of the origins of dynamics at the basis of 'mind' in people. The proportion could often be around 9:1, brain to environment. Two disparate lines of evidence might be taken to suggest this. The first has to do with the fact that, in primary visual cortex, around 90% of synaptic inputs to individual neurons originate from recurrent, intra-brain sources and only 10% from retinal ones, thus suggesting that 90% of the 'work' involved in visual mentality is down to the brain. The other has to do with the finding that our Cro-Magnon ancestors are said to have had brains around 10% larger, on average, than our own, which is surprising considering the huge costs in energy and maternal mortality of larger brains. However, they hadn't yet developed many of the social and

artifactual props to mentality that allow us to get our dinners from a supermarket, for instance, rather than having to manage the much more difficult task of hunting a mammoth. Maybe they needed 10% more neural bulk to make up for a lack of cultural 'bulk' in their minds!

Speculation aside, a useful consequence of acknowledging the dynamic and extended nature of mind is that it can be pictured as the content of vastly high dimensional dynamic state spaces encompassing brain, body and environment. Memories are represented in these spaces in the form of attractors. As the Lyapunov exponents relating to them will often be > 0, the attractors will often be 'strange' and may take all sorts of complex and beautiful forms.

Moreover, the dimensionality of the spaces will constantly be changing as the dynamical contributions of both brain and environment change, with consequences for the attractors that they harbour. The whole thing would look, if it could be visualized, a bit like a roiling, moiling cloudscape in a storm. Why is this picture useful?

The main benefit is that it offers an intuitive understanding of how we achieve our feats of recognition and recall, how we can manage motor actions with such precision or how we can learn to use tools as if they were natural extensions of our own bodies. As soon as an appropriate dynamical configuration is achieved, the associated attractor/memories, which have been previously learned, snap into existence almost instantaneously in the 'cloudscape' to guide neural activity down precisely determined pathways. The dominant attractors (i.e. those with the largest basins of attraction) comprise, for as long as they are present, something functionally equivalent to a 'global workspace'. There's no need for the temporally extensive computational processes that are so often envisaged to underlie our cognitive and performance abilities. It has always been very hard to explain how such computations could possibly achieve even quite ordinary tasks like almost instantly recognizing a particular face in a crowd. The reason that explanations have eluded us is probably because the brain mainly uses attractor dynamics to do its thing, but rarely or never uses computer-like sequential processing.

Another benefit worth briefly mentioning is that the picture provides a ready explanation of our need for sleep. Attractors that are called into existence for long periods of time will tend to become permanent features of the 'cloudscape'; they will tend to make permanent holes in it so to speak, thus greatly reducing future cognitive and behavioural flexibility with potentially disastrous consequences. Sleep, with its very different dynamics and consequent disruption of daytime cognitions, behaviours and their associated attractors, will restore flexibility. It's notable that the most consistent outcome of sleep deprivation experiments (other than death if they are continued for too long in rats!) is in fact reduced cognitive flexibility in humans and increasing behavioural rigidity in rats. There's also pretty good evidence that sleep plays some not very well understood role in assisting new learning and memory consolidation, but of course new attractors are likely to be better able to establish themselves if old ones that might interfere with their establishment are banished for a time.

The attractor cloudscape picture does point to how one might begin to offer solutions to a range of puzzles, but of course it is only an abstract concept. How might it manifest in real brains?

The neural instantiation of mind

There would seem to be two main requirements of a brain able to actualize an attractor dynamic 'cloudscape' of the sort described; namely that it should accommodate

vast ordered complexity and that functions associated with the complexity should relate to early stages of memory processes to allow learning of new attractors. The need for complexity follows from the enormously high notional dimensionality of the dynamic state space of 'mind'. Some feeling for what's needed can be gained from looking at two dimensional representations of tesseracts (four dimensional cubes), which are widely available online, and then recalling that brains need to 'represent' in three dimensions very complex shapes of attractors 'existing' in many thousands of notional dimensions.

Only fractal or pseudo-fractal (where the fractal dimension differs on different scales) structures are capable of achieving this. There are many examples of such structures in the brain, but of course the fractality has to be present temporally as well as spatially which effectively narrows the options down to varying ion fluxes with their associated electrical fields.

Can the options be narrowed any further? The requirement for a wide range of spatial scales of order in any fractal structure does point to a particular candidate ion as possibly being the primary mediator of instantiation of 'mind' in the brain, namely the calcium ion.

Ordered calcium ion fluxes are known to occur on spatial scales ranging from that of dendritic spines to assemblages of astrocytes that have many of the characteristics of syncytia because of their numerous gap junctions. These fluxes are driven by a wide range of circumstances which include fluxes of other ions and local electrical fields (to which calcium ions themselves contribute of course) along with the activity of dedicated calcium channels and uptake into calcium stores of one sort or another. They also operate on an equally wide range of temporal scales ranging from brief release of small packets of ions within dendritic spines to the relatively slow calcium 'waves' that have been observed to traverse groups of astrocytes. It's not clear that other ions show similar 'scaled' behaviour.

An implication of regarding 'mind' as dependent on fractally scaled calcium ion behaviour is that astrocytes must be expected to play essential roles in our cognitive and other abilities because they, not neurons, support the larger scales of order required by the picture; they must, in other words, support functions additional to the 'brain housekeeping' roles that were traditionally assigned to them. Evidence is beginning to accumulate that this is in fact the case; they do indeed appear to contribute directly to cognitive functions and resultant behaviour (Pereira and Furlan, 2009; Fields, 2013; Mitterauer, 2013; Bull, 2014).

Another benefit of a 'calcium ion' picture of mind is that it immediately meets the second requirement mentioned earlier; that any instantiation of mind should be intimately connected with early stages of memory processes. This is a requirement because it is essential to 'mind' that it should be capable of learning; of modification of outputs in the light of new incoming information which requires a capacity to establish new attractors in the 'cloudscape'. Moreover it must be capable of integrating different aspects of incoming information over time which is a memory dependent function.

Calcium ions directly activate CaMKll (a group of similar proteins widely distributed in the brain, comprising around 1.5% of total brain protein): the higher the local calcium ion concentration the longer the proteins remain activated until, over a critical local ion concentration, they switch to a permanently active state. They have a wide range of functions when activated including memory-related ones. Indeed activated states *are* a form of (mostly short term unless the activation state becomes

permanent) memory, but they also play a role in facilitation of synaptic long term potentiation which is known to be important to long-term memory.

All that has been proposed so far, however, relates to David Chalmers 'easy problems' only. The 'mind' that I've pictured has no obvious place for consciousness. How could that originate and how could it connect with mind?

The origins of consciousness

While our 'mind' may be an emergent property of brain calcium ion dynamics, it is becoming increasingly hard to believe that consciousness itself could have similar, purely emergent, origins in neural dynamics alone. There is ever increasing evidence from a wide range of sources that normal or even supernormal conscious experience can occur in association with highly compromised brains. For instance there are well authenticated cases of severe, chronic hydrocephalus who function normally despite having anatomically grossly abnormal brains. Even more striking are the many reports from cardiac arrest patients of vivid, elaborate experiences that apparently occurred when any normal brain function was known to be greatly impaired or even absent because their EEGs had 'flatlined' (van Lommel, 2013). There are far too many carefully authenticated reports of this sort nowadays to allow them to be explained away using any, or even all, of the range of strategies that were popular in the 1990s.

Clearly our consciousness has some basis far more robust than emergence from neural dynamics alone would allow. Nevertheless it equally clearly *does* map some of the contents of mind and generally relates to neural activity in *some* way. How can this circle be squared?

The currently most popular approach to providing a basis for resolving the conundrum is to propose that 'consciousness' is an inherent constituent of 'reality' along with matter and/or information, leading to concepts of 'property dualism' or its slightly weaker sibling 'dual aspect theory'. Neither of these approaches, however, allows any ready explanation for the apparent robustness in the face of neural malfunction that consciousness sometimes manifests. I therefore prefer to suppose that there is a form of 'neutral monism' at the basis of reality in which consciousness and matter comprise a fully integrated entity – a Jungian *unus mundus* as explored, for example, by Atmanspacher and Fuchs (2014).

The main difficulty with any such concept is that it is implicitly panpsychist or at least panprotopsychist, and is then faced with a 'combination problem' when it comes to accounting for our form of conscious experience. This is the problem of how to account for the integration of panpsychist elements into our elaborate and apparently seamless experience.

A clue to a possible solution is so familiar that it can be hard to see a particularly important implication. It is that our worlds are divided into realms of subjective experience within and objective matter out there. If there was ever a neutral monism, in other words, its former symmetry is broken as far as we are concerned. I've argued elsewhere (Nunn, 2013) that a plausible site for any such break lies in events associated with the manifestation of energy eigenstates, leading to the 'appearance' of what I dubbed 'scintillae of subjectivity' (SoS's) along with whatever the 'objective' manifestation of energy might be.

Each measured packet of energy that manifests in the 'objective' world is thus envisaged to be accompanied by a tiny packet of 'subjectivity'. Such packets have been dubbed 'qualions' (by Tal Hendel, personal communications, and others). Eccles and Popper (1984) used the term 'psychon' to refer to their rather

different concept of elementary packages of 'consciousness', but perhaps that's another word that could be hijacked and applied to the notion offered here. A problem with both of these terms, however, is that they may suggest something particle-like, along the lines of a photon, electron, neutron or whatever, but the suggestion here is that they actually refer to tiny packages of subjective time, totally unlike any 'objective' particle; hence my preference for the term 'SoS' (Nunn, 2016, forthcoming).

The SoS's can be envisaged as 'atoms' of consciousness just as inaccessible to our everyday conscious experience as are atoms of matter (because there's no way that they could get remembered as individual entities and thus become accessible to introspection). How might this concept help to resolve the 'combination problem'? How might, in other words, the SoS's join forces in a way that could allow conscious experience to map some of the content of 'mind'?

An answer lies in the Heisenberg time/energy uncertainty relationship which necessitates that any SoS's will have an intrinsic duration. Just as the virtual particles that play such essential roles in quantum field theory can have a wide range of energies because they manifest for very short durations, so SoS's can have a wide range of durations depending on how precisely the associated energy eigenstate is 'measured' by its environment. Eigenstates that are 'measured' with an uncertainty of 10^{-33} joules, for example, will be accompanied by SoS's enduring for 0.1 seconds. Any two such SoS's that occur within one another's lifetimes will overlap temporally and will thus, in a sense, integrate.

Provided the brain harbours energetic events that both vary in frequency and possess inherently small energy uncertainties, these events will get mapped into fields of SoS's of varying 'amplitude'. Aspects of the spatio-temporal dynamics of 'mind' will thus get translated into a tempero-spatial, 'subjective' format. Energy manifesting brain activity certainly does indeed occur with varying frequency; but whether the uncertainties of any of its individual energy eigenstates are ever sufficiently small to allow mapping into hypothetical SoS fields is not known (although calculable - in principle at least), but is perhaps not improbable. It would be serendipitous, but perhaps too much to hope for, that energies associated with calcium ion behaviour (e.g. ion/protein binding) will turn out to have the required small uncertainties as this would entail a direct mapping from 'mind' to field of consciousness according to the hypothesis.

Qualia

Any theory of consciousness that hopes to be taken seriously must offer an account of qualia, but only half of an account is implicit in the SoS field picture described above. What's missing is any basis for quale differentiation. Why is red experienced as red for instance and not as blue or the sound of a bell?

SoS fields may map some of the complexity of neural activity, translating it into 'subjective' form, but that by itself is never going to explain why different qualia do differ. My tentative answer to this question may well be judged to have strayed far into the territory of foolishness (see the 'Introduction'). Nevertheless I'll briefly describe it both to show that an answer, however crazy, is at least conceivable and because it also provides a bonus; a surprising answer to a very different fundamental question; namely why do we find ourselves in a universe with three spatial dimensions and not five or twenty or whatever?

The idea grew from Carl Jung's suggestion that his archetypes might 'exist' in the same sort of way that the natural numbers 'exist'. It struck me

that qualia have much in common with the prime numbers in that they are all generically similar but nevertheless irreducible to one another. Prime numbers did not at first seem promising candidates on which base a theory of qualia, but prime knots (and their equivalent braids) have exactly the same property of being both generically similar and irreducible. Could they offer any insight into the qualia differentiation problem?

Knot theory is a somewhat arcane branch of mathematics with surprising ramifications into many areas including quantum information theory. It turns out, for instance that there are surfaces (Seifert surfaces) topologically equivalent to knots, including prime knots. They, along with braids, might readily be envisaged to exist in the brain in some form or other. Could they, if mapped from neural into 'subjective' format, account for the irreducible differences between qualia? Maybe there was the tentative glimmering of a worthwhile idea here.

Recent developments suggest that the idea might actually be worth pursuing. It turns out that there may be connections between knot theory and the prime numbers since quantum knots may relate to the Riemann hypothesis (Sze Ng, 2012). The latter, if true as most mathematicians think is likely, defines a basis for the 'existence' of the prime numbers. Prime numbers and prime knots may thus share a common ontological basis for their distinctiveness. If both of them, why not qualia also, is my admittedly vague conjecture. Neural activity, some of which is irreducibly distinctive because it corresponds to prime knots, gets mapped into SoS fields and retains its irreducible distinctiveness while in that 'subjective' format – hence the distinctiveness of qualia.

If there is anything to this idea it immediately tells us why we inhabit three spatial dimensions since knots can exist only in three dimensions. They can't form in fewer and always unravel in more. Via the cosmological 'weak anthropic' principle, creatures with our sort of consciousness must therefore inevitably find themselves in a world of three spatial dimensions.

Future research directions

It is sometimes claimed that consciousness *per se* must always elude scientific study because it lacks objectivity, and it is indeed generally true that science has to confine itself to studying *reports* of consciousness whether made verbally by people or inferred from the behaviour of animals. However, the hypothesis offered here implies that more direct study may be possible, basically because of Newton's 'law' that action and reaction are equal and opposite. If energy fields of the brain in fact occur along with and modulate SoS fields, reciprocal effects of some sort can be expected which could, in principle, be studied scientifically.

Since SoS fields are envisaged as relating primarily to time/energy, whereas the behaviour of the objective world often relates more to position/momentum, any back action of conscious fields on the objective world might be expected to show itself most clearly in temporal and perhaps even energy-related anomalies. Some parapsychology findings (relating to precognition or psychokinesis for example) may ultimately prove relevant in this connection, but issues of interpretation would be difficult (to say the least!) given our current state of ignorance.

To start off with, an infant science needs plain and forceful phenomena to study; something analogous to the rocks falling from the sky (meteorites) which so outraged many 18th century natural philosophers because, according to their firm beliefs, that simply couldn't and shouldn't happen. Michael Faraday's iron filings patterns allowing visualization of magnetic

fields provide another example of the sort of thing needed. There are indeed frequent and varied reports of 'rocks from the sky' that could relate to beliefs about conscious mind, all of them often dismissed as 'merely anecdotal'. I'd like to focus on just one of these types of report as it raises particularly puzzling, and thus potentially fruitful, questions.

Penny Sartori (2014), an intensive care nurse, conducted a careful, prospective study of reports of near death experience which ultimately gained her a PhD but also attracted a good deal of publicity in the local and even national media. Lots of people, not included in her study, wrote to her about their own experiences. Some spontaneously reported odd physical phenomena following it, which tended to fade away over the course of time. These included light bulbs exploding in their presence and wristwatches mysteriously malfunctioning when worn by the reporter, but working normally when worn by others. One might be tempted to dismiss these claims were it not for the fact that relatives and friends of people who have actually died quite often say that, around the time of death and sometimes for a period after, similar anomalous events have occurred, such as electrical apparatus mysteriously switching itself on or clocks misbehaving (Fenwick, 2008).

It's perhaps not entirely foolish to suppose that SoS fields, when not firmly 'anchored' to a brain, might somehow induce physical phenomena that could be studied (despite the many practical difficulties that would no doubt be involved in trying to 'catch' them for study). How might the phenomena be produced is an obvious question. Is it by something analogous to a material force field; by local distortions of space-time, or of quantum probabilities, or of physical laws; by something else altogether?

Experiments could in principle be devised to distinguish between these possibilities that would tell us a lot about the nature of whatever it is that produces the phenomena.

Although the overall picture of consciousness offered here probably needs a 'rocks from the sky' approach if it is to develop, much of the detail is refutable (in principle) via neuroscientific approaches. Qualia have been envisaged as direct correlates of (1) fractally structured, energetic processes with (2) inherently very small energy uncertainties that may also (3) embody a knot-theoretical topology. Each of these three requirements is likely to become testable as brain imaging methods and their analyses improve.

Conclusions

Whatever one's opinion of the detail of the suggestions made in this paper, they at least provide an integrated picture of the sorts of relationship between the world, mind, brain and consciousness that may exist. Dynamic and informational aspects of the material world (especially socio-cultural aspects in the case of our own minds) and the brain integrate in 'mind' which is expressed in patterns of brain activity. Consciousness, divorced from a materiality that is integral with it in the foundations of reality, can nevertheless still mirror dynamic aspects of 'minds' as they are instantiated in brains, in what is very likely to prove a reciprocal relationship. Judging by recent trends in people's thinking about such matters, it's a picture that is unlikely to be wildly wrong overall, while the details offered here, correct or not, may help to indicate particularly useful research directions in relation to both mind (e.g. research into neuron/astrocyte interactions and the roles of memories of all sorts, whether genetic, personal or socio-cultural) and consciousness (e.g. research into reports of temporal and physical anomalies, and into neurofunctional

topologies associated with experience).

Acknowledgements

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