NEURAL CODES AND FIELDS AT THE MICROSCOPIC, MESOSCOPIC, MACROSCOPIC AND SYMBOLIC LEVELS

Seán Ó Nualláin

ABSTRACT: This paper makes two self-confessedly ambitious proposals. One is a theory of mind and world with an inventory of possible relations between the two of such generality that sensorimotor behaviour, potentially conscious cognition, and quantum mechanics fall out s special cases. The second is that the variety of neural codes is as multifarious as that of the domains in which mind functions; alternatively put, each cognitive "context" can be viewed as a field. Where cognitive "context" is lacking – a la quantum mechanics – the result is the quantum field theory of researchers like Schwinger.

This paper makes also makes the radical claim that dynamical systems theory provides solutions to problems plaguing neuroscience, rather than simply attractive models. It starts with the microscopic level, that of single neurons. A biologically realistic neuron model as a harmonic oscillator is shown to allow neurons do pseudo-Fourier transforms. While it is already known that spike timing becomes naturally causal in this model, we have also implemented a C++ simulation showing that it can operate on a raw power spectrum, and learning can be formulated as adjustment of delays. In short, the neural code at the microscopic level is, as Karl Pribram thought, the Fourier transform.

The mesoscopic and macroscopic (EEG) levels, which are at times connected in Freeman's writing, cater for the missing piece of "intentionality" ie how mind "intends – points to – things in the world. It is argued that nonequilibrium thermodynamics provides a good model here. The vocabulary of dynamical systems, starting as we already have with the periodic attractor of the harmonic oscillator qua pendulum, is proposed as a first approximation for what we need to do at the mesoscopic level.

That will finally bring us to the symbolic level, at which we experience, talk to each other, and do math. It is argued that formalisms that cater for co-ordinate free flows are more appropriate here than any others. Clearly, tensor calculus and lie groups will prove useful. We also consider physicists who have eschewed cognitive neuroscience as a failure and, with some brilliance, argue that physics ideas like pilot waves will prove crucial. While this will be the most speculative part of the paper, this area is developing rapidly and quietly like all successful revolutions.

KEYWORDS: Dynamical systems theory; Quantum field theory; Nonequilibrium thermodynamics; Walter Freeman; Neurodynamics; Sensorimotor; Cognitive and noetic; Coupled; Noumenal; Intentional

INTRODUCTION; NEURO THIS AND THAT AS THE NEW PSYCHOLOGISM?

> "The affirmation of therapeutic efficiency quantified by evaluations does not, according to him, suffice to explain the fascination which has driven numerous researchers to prefix "neuro" to their discipline; neuroeconomy, neurohistory, neuro this and that….one imagines that one day we'll speak of neuromanagement, neuropolitics or neurojournalism" (Roudinesco, 2018; translation by this author)

This rather beautiful instance of French exasperation is an appropriate summary of one of the main themes in this paper. A generation back, one would have made reference to the "psychology of "management, politics, and so on. This was rather viciously attacked in Frege's work as psychologism; briefly, it was the assumption that any given discipline could be cashed out in the language of cognitive schemes, stimuli and responses, or whatever the psychology *de jour* was. It will be argued here that a contemporary Frege would – again successfully – make the same argument against "neuro this and that".

While progress in neuroscience has been disappointingly slow, there are several things we know from our own brains' functioning. We process sense data well enough to perceive the world; we function as biological organisms effectively in that world; and we can also use language and do math, and are aware we can do so. Roughly speaking, these correspond to microscopic, mesoscopic/macroscopic and symbolic levels respectively.

Between them, Karl Pribram and Walter Freeman logged over 130 years of cutting-edge neuroscience, ranging from surgery to decades of the most exquisitely precise observations in the history of neurodynamics in Freeman's Berkeley lab. Therefore, when Freeman (2014) reviewed Pribram's intellectual autobiography at the end of their very long lives, the world took notice. The news was not good; current megaprojects in brain science in the EU, Asia and the USA were doomed. This has essentially been confirmed from the inside by Fregnac(2017) .

Why? One reason is the bugbear of mind science for centuries; a category error. Neural firing, in the "neuron doctrine", was misinterpreted as summarizing the informational interplay between brain and environment; indeed, to stretch the metaphor, between mind and world (Freeman 2014). In brain science, it is clear that study of neural impulses in isolation will reveal only plumbing; the recent salience of waves in neuroscience clearly needs to be supplemented with an articulated view of the field, the medium that they are waving. Is this medium the scalar field of EEG and fmri, the vector field required by any theory involving attractor surfaces, or do we assert that, since the suitably educated brain can understand tensors of rank/order 4, they too must be neurally implemented?

The *reductio ad absurdum* of the category error was surely the early 21st century over-interpretation of fmri results until doubts crystallized. It is not unfair to say that, following Gall's phrenology, a scalar field of subjective states was posited as explaining mind – and indeed psyche. In tandem with the recent debunking of the more absurd speculations, computer scientists began to see the virtues of transcending the scalar processing of traditional CPU's, speeding things up considerably with the vector processing of GPU's, while companies like Graphcore anticipate the next step in the tensor hierarchy as applied to computing.

In this context, it is worth noting that Freeman (ibid.) stipulates that field theory in brain science ended when Kohler mistakenly identified the vector fields of Gestalt with the scalar fields of EEG. Experimental observations confirmed that EEG did not reflect Gestalten in this manner, At this point, the floodgates opened; the concept of "Nerve energies" went the way of the ether, with impoverishment of the vocabulary of neuroscience as a result. Freeman later argued (Capolupo et al, 2013) for techniques whereby vector fields could indeed be read from the scalar fields of EEG.

Reed (1997) traces the history of the concept of "Nerve energies" from its predecessor – animal magnetism – through its assertion in the mid 19th century by Muller. Specific sensory modalities like vision and taste were seen to have specific "Nerve energies"; it is this notion that Freeman sees as being overthrown by information in the "neuron doctrine".

Freeman (2014) can be read as exhorting a refocusing on clouds of pulses at axons and waves of current in dendrites. Freeman (1999) posits pulse to wave to pulse conversion at each individual neuron. Yet, particularly in the light of Freeman's repeatedly expressed animus against symbols and representation, the result of a late conversion to European phenomenology represented by Heidegger and Merleau-Ponty, this may not be enough.

This paper attempts to extend his work in ways that a younger Walter, before the series of accidents that marred his old age, might have considered. The leitmotif is going to be nonlinearity. At the microscopic level, that of individual neurons, we are going to follow up the suggestion of Asl et al (2017) that the arrival of afferent signals at the synapses of neurons may be relatively independent of their arrival at the cell body. We will extend this finding to buttress our previous work (O Nualláin et al, 2009) postulating that manipulation of afferent delay allows groups of neurons implement a pseudo-Fourier transform as they struggle for survival in the massive die-off that occurs immediately after birth.

At the "mesoscopic" level – that of tens of thousands of neurons and upward – we find that that vocabulary of dynamical systems qua attractor surfaces becomes useful. We have stepped into vector field theory at this point, and we may find that quantum field theory (QFT) provides a more useful representation. In a later paper (Vitiello et al, in preparation)we argue, following Freeman and Vitiello, that quantum field theory (QFT) provides a more elliptical, encompassing and veridical formalism as dynamical systems engage with the highly dissipative system that is the brain and its environment. The fit between QFT and the Freeman observations is impressive.

Specifically Freeman (2003) defined the upper levels as

> "The second level is mesoscopic. Observers measure the summed dendritic potentials of masses of neurons and acquire evidence of local mean fields (LMF). The third level is macroscopic. Observers use imaging techniques such as fmri to measure activity patterns in whole brains" .

The mesoscopic level can be simulated by summing over the random firing of tens of thousands of neurons and observed by invasive techniques such s ECOG; the macroscopic level is for Freeman an observational process, like FMRI or EEG, that does not require invasive techniques.

It is fair to say that there is a link with the macroscopic in Quantum mechanics, particularly as Freeman would prefer to end explanation with entities at this level without venturing into the semantics of words and other such entities in order to explain mind.

The search for the neural code is perennial. We are going to argue that there are many such, implemented in scalar, vector and other fields. At the microscopic level, where a scalar field obtains in a frenzy of Brownian motion resembling a gas state, we will argue that neurons may perform a Gabor or Fourier transform. Then the output from this level is cleansed by the "brain laundry" which feeds into an emergent dynamic of attractors, including chaotic such, and mapped at the macroscopic level by EEG.

We end by going where Walter dared - or perhaps preferred! - not; into the world of symbols and representations. At this final level, the symbolic, we run into a series of paradoxes. Freeman (1999) argued that the "brain laundry" meant that one's cognition was "solipsistic"; its roots in sensory experience were lost as the stains mapping our contact with the world are washed out. Yet we manage to communicate with each other, which Freeman put down to intersubjectivity through a type of resonance, with his favorite activity of dancing being the paradigmatic case.

That may not be adequate to describe how we understand math and other symbols systems. We argue that math is at times capable of the most elliptical and veridical description of reality that can reliably be communicated. It is possible that we all have a more compressed "solipsistic" version of each of its concepts as the peculiarities of our experience dictate. But to communicate our insights, we take advantage of the at times cumbersome apparatus of symbols in math that has developed over millennia. A similar argument holds for language, although as edifiers like Wittgenstein have suggested, the situation is far less clear-cut in "natural" language than math (O Nualláin 2003).

Freeman continually cites von Neumann's observation that, unlike serial computers, human brain function could not possibly involve much logical depth. Our decisions have to be made very quickly; better, surely, to load balance the task over a massively parallel system? Right on cue, in the teens of the present century, DeepMind proved that such a system could perform a range of AI tasks. In our edited collection(1997) Hoffmann proposed adaptations of category theory and Lie groups as the best equivalent of what is going on in the human brain in a manner consistent with the von Neumann observation.

But is that the full story? Many savants perform at levels comparable to computers – at least in their own micro-specified domain of expertise like knowing the day of the week on a random date. Some "normal" humans can drive a car, text, and hold a conversation, all at the same time, tasks known to be non-trivial for robots.

Culture seems to program our brains to perform at astoundingly high levels; this was the initial "extended mind" hypothesis, as pioneered by Ed Hutchins (see O Nualláin, 2003).

So this paper ends with a respectful disagreement with Freeman; we have found ways to "offload" computational tasks onto our friends, and on to mnemonics and other cognitive aids in the external world that makes symbolic, embodied functioning natural and effective.

Can math be reduced to a description of the psychological operations underpinning its apprehension by the mind, or is this a category error in some sense? If so, precisely in what sense?

For math, as we described, the "unreasonable effectiveness" of certain formalisms in the physical sciences is indeed mysterious; the fact that the culture of math has developed an accepted language may – perhaps fortunately – hide from us the idiosyncrasies of how we implement this in co-ordinate free flows that may indeed be the brain's native language in the "solipsistic" post brain laundry world we would rather not inhabit as our home.

It is universal at this point to insist that the brain not only uses vector representations, themselves a higher order tensor than scalars, but sparsifies them in various ways, including dimensionality reduction and information decorrelation in the signal which parallels state-vector reduction. How should we handle "information", particularly at the interface between Cognitive Science and neuroscience , the bugbear of Freeman (2014)?

One of the few points of consensus about its foundations is that Cognitive Science deals with mind as an informational system. But what is information? Is it to be regarded as synonymous with "entropy" a la Susskind, or indeed capable of generating and evincing properties of mass due to its links with uncertainty as Seth Lloyd suggests? For the later Freeman, issues of symbolic behaviour could be subsumed under the rubric of information qua entropy. Let us now home in on symbols in Cognitive Science.

The received history of Cog Sci has often focused on the poverty of the stimulus, an "in principle" argument from Chomsky's notorious review of Skinner. Yet that argument has not worn well, with the data in question more available than Chomsky thought. Can we can then revisit Chomsky's argument wrt the fact there is no guarantee that we can induce the correct context sensitive grammar from raw linguistic data, an argument that holds a fortiori for neural impulse?

At the Hixon symposium in the late 1940's ,it was argued purely on speed grounds that the beginning of sentences cannot be the stimulus generating the response that comprises the rest of the sentence as certain trends of behaviorism thought. In short, there had to be some onboard processing. Does the notion of a mind with a capacity for recursion and internal representation arise naturally, or as a considerable stretch, from this?.

Given the arguably non-Euclidean nature of spacetime both as an entity in mathematical physics and our natural representation of it, what is the status even of sophisticated constructivist theories like Piaget's that assume a Euclidean space? These are deep questions; as we end the teens of the 21st century, we can be sure that its best minds will still be engaged with them for most of its progress.

There are a few in-principle arguments that pertain. The first was due to Chomsky and his followers; it is that human languages evince a systematic structure, and that this has a certain formal complexity. Cognitive science must allow at least that tensors able to handle context-free grammars are used to model the brain. It also must eschew behaviorism as a program to explain all, and reinstate the algorithm as an explanatory device.

The second is due to what we know about the more remote achievements of the human mind. Ricci flow involves a tensor of order 4; somehow mathematicians can handle this. It is now absurd to suggest that the scalars used in fmri "explanation" are in any way adequate. In fact, no explanation of human cognitive function can be accepted that does not show formal capacity to handle all achievements of human cognition, as described formally.

The study of these formalisms and their application is the holy grail of Cognitive science, which is a superset of cognitive neuroscience and is NOT reducible to a neuroscience that eschews these formalisms. It is not surprising that many of the formalisms that obtain – like tensors and Lie groups –are precisely the ones found useful in physics. This does not reduce physics to cognitive science, except in the trivial sense that we can in retrospect explain what the physicist has just done, in a theory that will often come after the fact

So we need acquaintance with context free grammars, with partially recursive functions, and with the set theory that goes with them. It is almost inevitable that we eventually will need to understand how the metric tensor changes in curved space in order to understand both symbolic and sensorimotor behaviour, the latter in animals and the former also in biological codes.

In order to prepare for the most audacious claim of the is paper, we must secure definitions of some terminology. Context in formal language theory is a formal construct; it refers to the expressive power of the formalisms in terms of the restrictions imposable (see my 2007 paper).Context free grammars correspond roughly to scalars. Context sensitive grammars – and there is suspicion that human natural languages like Swiss German fall in this category – are capable of restrictions in rewriting resulting in heightened recursive capacity (ibid). This is distinct from "context " as we colloquially use it for example in the author's right not to be quoted out of context.

That latter meaning of "context ", it is argued here as in my earlier work (2003) is a specific interaction of world knowledge and symbolic competence to create what is in effect a field. Moreover, that field, like the gravitational field in general relativity, is distorted as the domain becomes ever further specified. Just as a stem cell, will differentiate to a liver cell if placed in the liver, so will syntax adopt the selectional restrictions normally associated with semantics if the domain is sufficiently restricted to create a "sublanguage". That in brief is how SIRI can seem so intelligent although it is quite primitive AI; in Wittgensteinian terms , it knows the language-game is a question in a specific domain, and need be ready only for a set of very syntactically restricted forms.

Vern Cerf and his colleagues found that their TCP/IP could scale up to handle the current massive size of the internet. Let us propose a TCP/IP of mentation.

SENSORIMOTOR, COGNITIVE AND NOETIC; COUPLED, NOUMENAL AND INTENTIONAL

In the first place, as outlined in the introduction and several chapters in my 2000 book, we can make a distinction between, "coupled" and "decoupled" mentation . The former was previously identified with egocentric sensory-perceptual loops ; yet these are sufficient to learn a room sufficiently to vacuum it, as the Roomba shows. The latter includes the kind of symbolic representation attempted by "Shakey" and "Hacker" at Stanford - ironically almost 50 years ago -and doomed to failure even with today's computers as a result of combinatorial explosion.

A useful way to think about this is the contrast between asking directions from people local to an area and SIRI. Local know how to get to their neighbors' homes and other places – but that knowledge is often egocentric and incommunicable. Several country miles later, you still have not found the house. By contrast, SIRI has your GPS co-ordinates and can relate this to an allocentric map that includes your location. In a final wrinkle, it is possible to combine the virtues of both with egocentric movement which has a map to refer to when stuck.

"Decoupled" mentation has also been termed "allocentric", that is representation with a model that includes oneself as another object in the world. Of course, the realization that we're boring and confusing others – perhaps with this article! – is allocentric and decoupled. Yet the most effective sensorimotor action is egocentric, in that the environment is operationally treated as sensory-perceptual loops, in an overall framework that is allocentric. We can term this "relativistic" at the sensorimotor level. It arises as a result of intentional process, in which mind is working to construe the external world veridically in the absence of immediate stimuli;

"This is the essence of intentionality…quintessentially, a strong reaction to a stimulus that isn't there" (Freeman, 1999, P 95).

Failing to realize that we're boring and confusing others is coupled/egocentric at the cognitive level. To arrive at the relativistic stage at the noetic level – which indeed corresponds to special relativity - we must consider that, in order to rescue physical law, space and time must be made relative to the observer. Borrowing from and slightly traducing Kant, we describe the path to considering ourselves as objects in order to know "the nature of things" as a "noumenal" one.

Mentation, therefore, in an epistemological mode admits of sensorimotor, cognitive and noetic modes. In a metaphysical register , there is initially a dichotomy between coupled and decoupled; having embarked on a noumenal search in the decoupled realm to find our true roles in the world, we transverse an intentional bridge to arrive at a relativistic view.

The sensorimotor mode begins, like the other two, in a "coupled" register. The Roomba can learn a room simply in "reinforcement learning" or Skinnerian conditioning in terms of the set of possible actions it can perform on that room. Decoupling in the sensorimotor mode begins with intentionality which so far only biological organisms possess; the organism is no longer a slave to immediate stimuli but can allot processing resources to, for example, the dog that did not bark in the night. Eventually, a model of the world is built with "allocentric" features in that the organism includes itself as an object in the model. None of this requires subjective experience.

Cognition a fortiori involves qualia/ subjective experience, perhaps because it involves a synthesis of many hitherto distinct evolutionary processes like thought and language and delivers results at a rate that consciousness can sample – tenths of seconds (see my 2003

book for the late Richard Cromer's Vygotskyan exploration of this point). Again, we begin with a "coupled" register in which we are conformist in the intersubjective realm, unable to distinguish law from justice in the moral realm, and subaltern in power relations. It is perhaps no coincidence that breaking from this into personal authenticity, Kohlbergian morality, and political enlightenment has historically been identified with consciousness-raising and lack of egocentricity. .

Aristotle identified as "techne" relations like knowledge and skill which do not require transformation of the subject in this way and can remain "coupled". We often attempt to automate them, ie chunk them to facilitate greater skill. These can be thought of as "intentional" achievements. Galilean relativity is a next step in the noumenal register in the cognitive mode, as exemplified by the charming film "Agora" about the great Alexandrian female mathematician we know as Hypatia.

Arguably, while Einsteinian special relativity uses some cognitive and thus "naïve physics" arguments, it is best thought of as noetic. The noetic mode uses the "unreasonable effectiveness" of math initially in a coupled register. This means we simply fill in values for variables, shut up and calculate.

An initial decoupled achievement in the noetic mode is the use of formalisms like the Hamiltonian and Lagrangian that have to be re-engineered for each application. At a next stage in the noumenal path in the noetic mode, von Neumann established that the line between system and apparatus can be put at any point. The math here – as in the noetic mode in general – uses Platonic symbols, and the processes involved, like changing the wave function of the universe, may not be accessible to consciousness.

Only noesis seems a priori a QM enabler. What Stapp (2017) is referring to is a bridge further still. It is when the noumenal search ends with the capacity to immediately affect the external world, which can be thought of as a moment in which the noumenal becomes numinous.

That written, and in the allocentric hope that I still have readers, let us peruse some less complex arguments about neuroscience.

THE MICROSCOPIC LEVEL; INDIVIDUAL NEURONS AND SENSORY DATA

> "Genuine chaos…sensitivity to initial conditions, existence of random itineraries, common occurrence of random itineraries, and cake-mix periodicity/a periodicity" (Stewart, 1990, 124)

Much ink has been wasted on trying to explain the concepts in chaos/complex systems. Let us try and arrive at a common vocabulary. Dynamical systems theory, as the term suggests, begins with first order differential equations (dy/dx) specifying movement in several dimensions (eg x,y,z)). It segues into consideration of on-linear systems like a pendulum in which the exponent is greater than 1 (thus d**2y/dx**2).

When systems like the weather are explored, unexpected complexity enters. Ultimately, the weather is seen to be governed by a "chaotic attractor", which has unexpected regimes of order resembling those in fractals (Stewart, 1989). We shall see this is Freeman's work; he was also very exercised by phase transitions, often the result of the type of bifurcation we are about to discuss. In particular, he argued the brain can shift from a "gas" to "liquid" regime. Bifurcations, sinks saddle nodes and sources were anticipated by Poincare and the topological math he developed was critical in the development of chaos/complex systems aka chaoplexity aka dynamical systems.

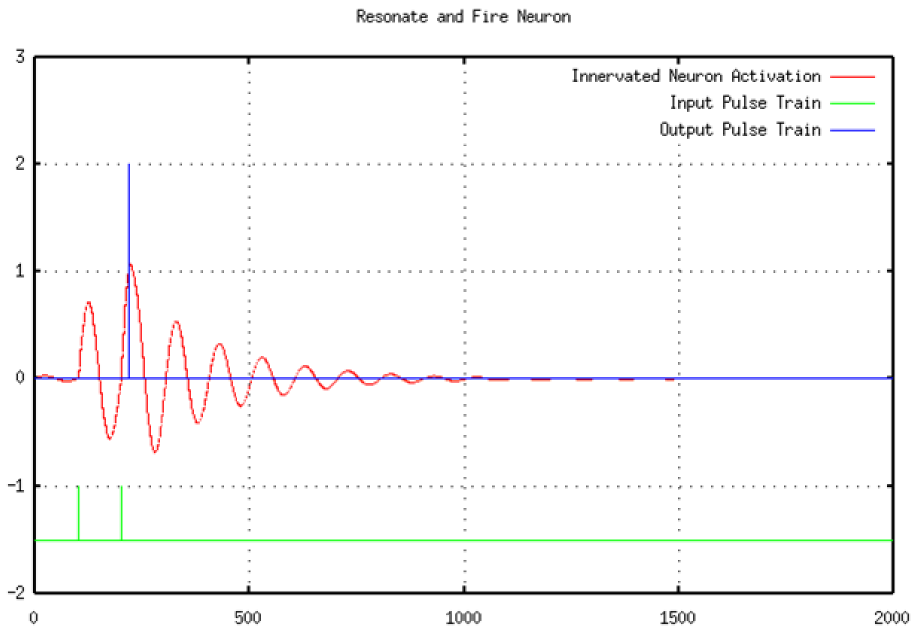
O Nualláin et al (2009) make the radical claim that groups of neurons in a scalar field can perform Fourier transforms. To motivate this, we harked back to the venerable Hodgkin-Huxley model of the neuron. This described it as a resonator or an integrator; if the rest state disappears through Andronov-Hopf, then the neuron behaves as the former and selects multiples of its eigenfrequency in afferent signals in "choosing" whether to fire. If, on the other hand, the saddle node option is taken in the bifurcation arising from the rest state of the neuron, it acts as an integrator, with the textbook model of inputs at higher frequency causing it to fire seen to obtain.

Indeed, the textbook integrate-and-fire (INF) model emerges from the resonate-and-fire model if the wavelength of the oscillation of the membrane potential is long, making its frequency low. In short, INF is a subset of RNF. The second salient fact is that neurons need to continue firing in order to survive. A massive death of neurons occurs straight after birth, leading us to suspect that what is happening is that neurons that fail to find a definite role in the processing of sensory data will die.

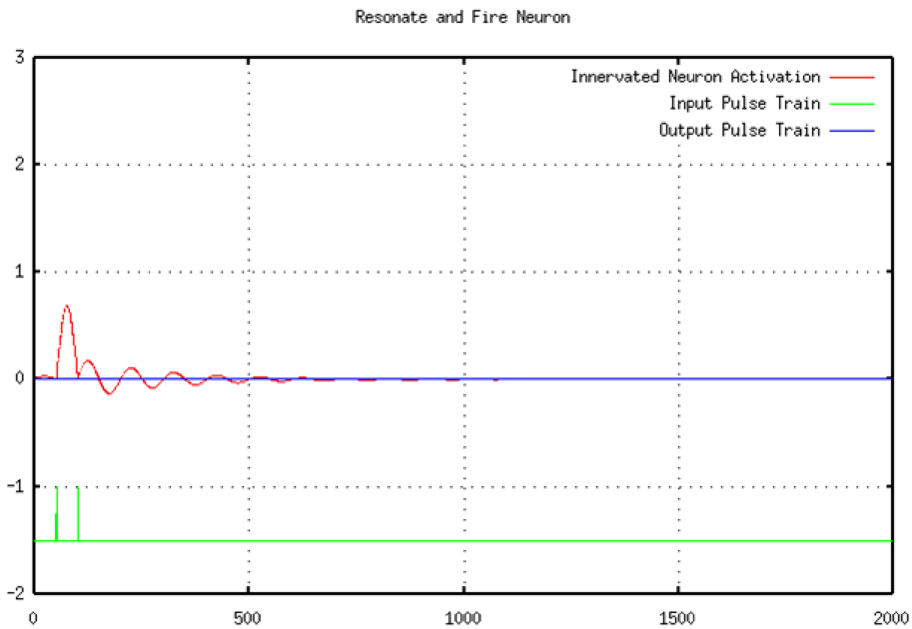
Our model is that of an idealized harmonic oscillator; the membrane potential oscillates, and a damping term caters for the refractory period immediately after firing. It is now commonplace to accept that the timing of afferent impulses is at least as important as their frequency for firing to occur. This falls out naturally from our model.

"Each cortical neuron connects with only 1% of the 10**6 neurons within the diameter of its dendritic tree" (Freeman, 2003).In terms of the neonate, we suggest that neurons compete to position themselves a la the screen in the Young's slits experiment, to assure themselves of firing often as a result of constructive interference in order to ensure their survival. They receive inputs from their afferents, which are similarly interested in their own survival. The entire nexus, together, can a la the Fourier transform a power spectrum of frequency, amplitude and phase into time.

The diagram shows impulses from two afferent neurons arriving in synch, causing the target neuron to fire;



On the other hand, they arrive out of sych in this example and no firing occurs.



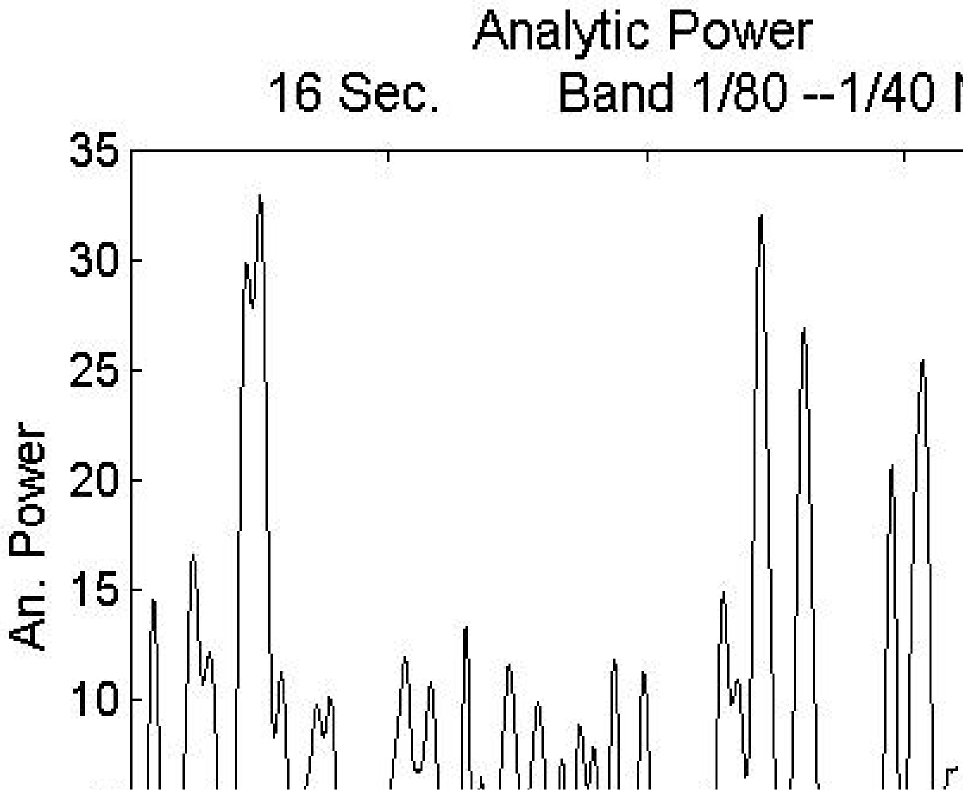
Until recently, the most controversial part of our schema, and the one that Freeman disagreed with, was the individual neuron's adjustment of its delays. He argued that this was beyond the processing ability of individual neurons. Since his death, Asl et al (2017) have given us preliminary solace, It had already been known that neurons will amplify the signal from neuronal input they perceive as distal. We model this with propagation delay which can be simulated with an array of time steps, each holding the values of the neuronal input at that time. What Asl et al (2017) have added is a simulation of how a decoupling of the afferent at the cell body and at the synapses could be implemented.

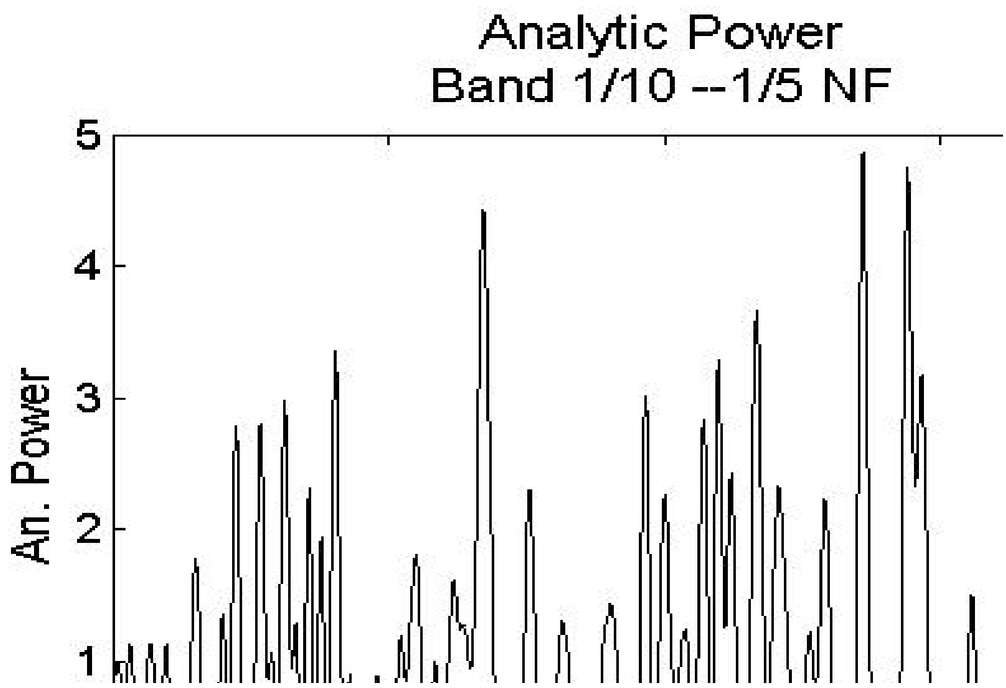
THE MESOSCOPIC AND MACROSCOPIC LEVELS; FROM STRANGE ATTRACTORS TO QUANTUM FIELD THEORY (QFT)

We can superimpose waves occurring at the mesoscopic level on the Brownian motion of the random firing of neurons to see power dips occurring several times a second due the superimpositions of fast gamma (40-80 Hz) on the random firing of individual neurons.

If we do the same superimposition for any of the other wave forms in the brain (theta, gamma) we find exactly the same shape over a different time interval. Freeman believed that this fractal self-similarity was the main process that facilitated the brain's changing state almost instantaneously.

The following diagrams show self-similarity in real data over theta and gamma waves in power with the x-axis being time with 2 sec for the second diagram;





Let us now outline the view here. In the first phase, a pseudo-Fourier transform is performed by individual neurons acting together in a scalar field. This converts the raw frequencies into a time signal. This is turn is conveyed to the mesoscopic "attractor landscape" with a basin of each attractor initially being selected. The initial signal is now obliterated in the "brain laundry" and cannot be retrieved.

The attractor evolves in a way that reflects the subject's experience with amplitude modulation of the carrier wave reflecting the meaning for the subject. A process called "preafference" allows the subject continually to check his experience against what is occurring in the external world. Alternatively put, in the far from thermodynamic equilibrium scenario, the internal state is stabilized by the external world. This is the quintessence of intentionality.

The introduction to my 2008 paper describes how the attractor system generates a "wave packet" that propagates through the cortex. In the first place, it is worth noting that Walter's is a thoroughly neurobiological account. While much of his vocabulary draws on his considerable math and engineering background, he eschews the cognitive and symbolic lexicon.

Thus, there is no reference to Grammars, to Piagetian formal operations, to phenomenal/conscious experience or the like; the goal is consistent with Occam's razor. It is fair to say that he stops at the sensorimotor level, eschewing methodologically the cognitive and noetic, while (as an artist, dancer and poet) being fully aware of their reality.

Thus, we find references to perception-action cycles, to phase transitions, to attractors, and to the propagation of entities in state-space. Methodologies recommended include diffusion tensor imaging, nonequilibrium thermodynamics and much else that may seem quaint only in a world in which it is assumed that since we have mapped psychological predicates onto locations in the brain, neuroscience is basically over, is it not?

It is significant, therefore, that even such ascesis allows abstraction and generalization; recall of memories; spatial delocalization and readout by downsampling the delocalized amplitude modifications. Chomsky may not be name-checked but Merleau-Ponty will be referenced.

It is accepted, in the other hand, that the animals transform the stimulus while processing it and the beta and gamma waves carry amplitude modifications indicating the animal's memories of past states aimed at future states of the evolving agent . These may be read out with diffusion tensor imaging.

The entorhinal cortex sends out a sparse but global signal which is the basis for the individual expectation of the next action. Clearly, consciousness will have as a signature a sparsely sampled version of this signal.

A critical innovation is that knowledge is to be distinguished from mere information partly by the "condensed state of the global cortical neuropil". For our purposes, perhaps the critical notion is that the neocortex is a single organ with no glial barriers. This allows a phase transition in which the entire cortex is sustaining a fluctuation and this is the basis for awareness in freeman's view.

Freeman (1999, 71) shows how a chaotic attractor can come to exist in the olfactory cortex. The later Freeman still held onto his notion that attractor surfaces were the correct terms in which to describe much of cortical function. However, influenced by Vitiello, he now believed that quantum field theory provided a more elliptical and veridical language for cortical function.

In particular, symmetry breaking of the QFT equations led to states with long-range order like crystal; the existence of these states in biological systems had been hypothesized by Di Giudice. In fact, the primal event in Freeman's late neurodynamics was the transitions for a random gas-type phase to a coherent liquid phase.

In his final stage, Freeman tended toward use of QFT to sustain a wholly objectivist account of human mentation. Memory is considered as a set of basins of attraction or alternatively the ground states of QFT; information and knowledge can be construed in terms of information and entropy, a move presaged in physics. The self/subjectivity is a lull in the ergodic itinerary of energetic systems.

HOW SYMBOLS ACTUALLY WORK – OR, WHAT QFT, THEATER OF THE ABSURD, AND NONSENSE HAVE IN COMMON

> "Colourless green ideas dream furiously" – Noam Chomsky

> "We're magicians" Samuel Beckett, waiting for Godot

> "the quantum state evolves via a generalization of the Schrödinger equation…the first phase of process 1, namely observers" choice of probing action, can be regarded as a local process, confined to a local region, whereas the second phase, namely Nature's choice of response, turns out to be…faster than light!" (Stapp, 2017, p. 39)

The unenviable task of this section is to convince the reader that there is a common underlying theme between these three quotations. Let us first revisit Neurodynamics.

The reader may be confused by the ping-pong between QFT and the vocabulary of dynamical systems, What matters is that sensory data are used preferentially to select a set of processes latent in the brain's function. These may be conceived of as attractors, Hopfield nets, or the ground states of QFT. Moreover, they are already biased by topdown effects;

> "The macroscopic feedback messages are order parameters that bias the attractor landscapes of the sensory cortices in preafference" (Freeman, 1999, 113).

These top down effects are due to whatever the agent is engaged with at the given time; fleeing from a hunter, reading a book, dancing. Now we come to what Freeman (2014) was hinting at; these "order parameters" can be viewed as what we colloquially call "context" or what may better be referred to as "domain" and are effectively fields. Moreover, like gravitational fields, they increase in intensity – the parallel to approaching a massive body is restricting the domain. Finally, they create neural codes by biasing through pre-afference.

So every linguistic domain (reading about diplomatic visits, spy thrillers…and so on ad infinitum) is a field creating a neural code. Clearly, so is every social and physical situation that differentially causes pre-afference. The search for a neural code above the microscopic level is quixotic and doomed. Let us try and cash this out in some examples.

The received view of language processing construed a "pipeline" model from phonetics through word morphology to syntax, semantics and pragmatics. Clearly, we do not need all this. Someone says "FIRE!" and you run. They say it faintly, but you also smell burning, and pre-afference bias works to save you by running.

In the fractious landscape of philosophy of language in the 20 the century, Wittgenstein stands out (see my 2003 book). He argued that St Augustine's theory of language maps words to reality in this way. Moreover, it clearly works in restricted behavioral contexts, like a laborer saying" brick" to his helper when it's time for another one. For more complex situations, the earlier Wittgenstein thought that a system resembling symbolic AI could work; he later refuted this, arguing that we had to look at "language-games", language in behavioral contexts.

One such was "fragen", asking questions. Several billion are asked of SIRI every week, As already mentioned, SIRI is quite primitive; it functions in a sublanguage, in which what would be semantic issues are appropriated by the syntax, or indeed by keywords. This is a first restriction of domain, and works very well and you in general end at the correct destination.

If, however, we use Google translate on a better newspaper like "Le monde", it will get it perhaps 98% right. The fact that this is nowhere near good enough and that these systems will remain toys will not concern us here; for the moment, suffice to say that a mixture of statistics, canned text, syntax and semantics gives good results. The problem, of course, is that the missing 2% is precisely the precision and nuance that we pay for in a good text, as distinct from Twitter feeds.

The point here is different; it is that the domain is less restricted. Now take the three examples that started this section. Chomsky's example is syntactically, correct, but does not specify a domain. The term I prefer here is that we cannot get to interpretation, processing in a field specified by the domain. Indeed, micro-specification of the domain might itself elicit meaning. We are stuck at a prior process I call "analysis", where we bring syntactic knowledge to bear without physical experience and "world knowledge".

Beckett's theater of the absurd often strands attendees in "analysis" for higher reasons for a whole night. Elsewhere I have argued that its absurdist ethos is the closest we come to the apparent nihilism of QM in "ordinary" experience. Two tramps by a roadside wait for Godot who never comes. They label each other magicians as they find reasons to pretend they exist. Another character, Lucky, launches into an anti – theophany featuring an "aphasic" god. It seems the ultimate in bourgeois uselessness of mid 20th century art. In 1993 audiences braved snipers' bullets to see it, candlelit, in Sarajevo, Likewise it was used as a metaphor for Arab-Israeli relations in Haifa and for similar ends in South Africa.

While our final writer, Henry Stapp, is a good prose stylist, the scenario is just as cognitively bleak. In quantum mechanics, we have left our experience and "world knowledge" behind. Moreover, we seem to be left with a mind at large in a cosmos described in Tomonaga-Schwinger field theory.

This mind is immensely powerful. It causes a' "collapse/reduction" of the quantum state of the universe that occurs at a single instant' (Stapp, ibid.). We not only affect the state of the universe by measurement a la the twin slits experiment; we determine it. In the final section of this paper, we are going to explore that point. Whether our paper in preparation (Vitiello et al, in preparation) will shed light on how QFT can be applied homogeneously to the cosmos and brain remains to be seen.

QUANTUM EFFECTS IN THE BRAIN

The classical debunking of quantum mind is Tegmark (2000) and this may condemn this media-friendly academic to be a footnote in history along with Kelvin's invective against heavier-than-air flight. Al-Khalili et al (2014, 173-178) enumerate the findings of coherent quantum states at physiological temperatures in biological systems that Tegmark ruled against. Moreover, as my 2013 paper pointed out, Tegmark seems innocent of gap junctions and ephatic mechanisms which allow "action at a distance" in the cortex. The latter would emerge naturally from Bose-Einstein condensates of the type Vitiello hypothesizes for the brain, following Froehlich and Del Giudice.

The causal role of quantum processes in mentation aka the "quantum mind" hypothesis is still a controversial issue. Given the increasing success of current AI systems that function in what were until recently regarded as specifically human cognitive domains, and the incommensurability of the time scales involved between the conscious moment and decoherence, there would seem to be good reasons for ignoring quantum processes altogether.

Yet the counter-arguments that quantum mechanics is the most successful theory in scientific history, with a degree of precision to 12 places of decimals or more, and that it can be interpreted with psychological predicates included, seem to this writer to have traction. Before considering quantum ontologies, this paper examined the instrument by which we study the world; the human mind itself. If we fail in steadying the telescope, we cannot look at the moon. As the author has already reviewed Stapp (2017) in a peer-reviewed journal much of the discussion here is more discursive than would otherwise be the case.

Many objectivist, that is third-person, accounts of mind have persisted for decades. For quantum processes, the most famous account that does not involve observers is decoherence (Zurek, 1991, 2002). Quantum processes cannot remain coherent for long, and herculean efforts are being made at companies like Google to forestall this environmental interference for as long as possible.. We looked at what are now the classical arguments against quantum effects in the brain, arguments weakened by discoveries in the aughts (Al-Khalili et al 2014).

The chorus of Indian thinkers who claim charter from their ancient Vedanta, and current technical excellence, to posit a cosmos that (like Stapp's) is fundamentally mental will then be discussed. These and other quantum ontologies will be our penultimate stop.

The final conclusion – that the situation is infinitely more complex than any of these thinkers realize – may please few. It does have the virtue of continuity with attested discoveries in robotics, in cognitive science, and venerable western philosophy. Conversely, it may save the quantum mind hypothesis from some of its many critics.

RELATIVE TO WHAT? – QFT VERSUS STAPP'S REALISTICALLY INTERPRETED ORTHODOX RELATIVISTIC QFT (RIORQFT)

Relativity will emerge from this paper hopefully transformed in the reader's mind – itself of course a relativistic achievement in the sense we will introduce! Stapp (2017, 39) proposes adopting an extension to QFT independently discovered by Tomonaga and Schwinger. The details do not concern us; they are focused on outlawing backward-in-time causality (retrocausality) and faster-than-light (FTL) processes by constraining the geometry of the space used. Stapp (op. cit.) adds several wrinkles; as a result of process 1, in which nature becomes causal in making a choice, the wave function of the universe changes. FTL becomes possible, and indeed necessary.

Other researchers like Freeman (Capolupo et al., 2013) tend toward use of quantum field theory (QFT) to sustain a wholly objectivist account of human mentation. Memory is considered as a set of basins of attraction or alternatively the ground states of QFT; information and knowledge can be construed in terms of information and entropy, a move presaged in physics. The self/subjectivity is a lull in the ergodic itinerary of energetic systems. Vitiello's otherwise excellent English lacks that word to reflect persistent but acyclic itineraries; his prolific writings (1995, 2001; Freeman et al 2006, 2012) are an explicitly non-relativistic complement to Stapp (2017).

Of course, this objectivism was debuted by Seth Lloyd in his account of cosmogony; galaxies reflect a Heisenbergian uncertainty at the moment of genesis. This is mentioned because the perspective of Henry Stapp is radically different, and vehemently argues against determinism. The conclusion of this paper is that we have a long way to go before we can begin to accept this argument, but the journey may be worth it.

Schrödinger's cat (wanted – dead or alive!) and other such paradoxes hinge on an assumed discontinuity between the microscopic and macroscopic (the author is aware that phenomena like cryogenic versions of Weber bars make this distinction less relevant; all the better for the formalism about to be introduced);

> "The inadequacy of this approach has become apparent as a result of relatively recent developments: A cryogenic version of the Weber bar—a gravity-wave detector— must be treated as a quantum harmonic oscillator even though it may weigh a ton …nonclassical squeezed states can describe oscillations of suitably prepared electromagnetic fields with macroscopic numbers of photons Finally, quantum states associated with the currents of superconducting Josephson junctions involve macroscopic numbers of electrons, but still they can tunnel" (Zurek, 2002)

A microscopic event like radioactive decay becomes related to a macroscopic event like being alive.(Please note that these terms are being used to mean different things to their referents in the neuroscience descriptions above.)In like fashion, it has been speculated that Wheeler's "participatory universe" has as a consequence lower animals looking at the stars and resolving superpositions. This section argues that there are principled reasons to believe that cannot happen.

It is clear that we have moved far from cognition as construed by researchers like Piaget, Bruner, and so on – see my 2003 book. This kind of act of mentation which uses the "unreasonable effectiveness" of math we termed "noetic" It must also be distinguished from the sensory-perceptual loops described so well by Merleau-Ponty (ibid.) so we posited 3 epistemological realms of human mentation – the sensorimotor, cognitive and noetic.

In short, we are going to regard the issue of mind/world as primary and we will find that quantum ontologies become an issue only in a restricted set of possible mind/world relationships. Alternatively put, the sensorimotor and cognitive deal solely with the classical world; while most of noetic mentation also deals with the classical world, a component deals with the quantum world.

It does so precisely because the line between observer and observed can be put at any point, so the subject-object differentiation that noetic mentation shares with the sensorimotor and cognitive becomes an epistemological reality, as distinct from a habit of perception as in the other two cases.

This will buy us much. In the first place, we now have a principled reason – be it right or wrong - to believe that the cat's looking at the stars does not give it quantum observer status, a role that we can provisionally assign to the "noetic" as distinct from the sensory-perceptual loops that the cat's lack of symbols condemns it to.. This is a more fundamental and important point than may at first seem to be the case; neo-

Bohmians like Sarftti (see our 2017 collection) argue that every biological system is capable of a "back-reaction" changing the pilot wave.

Yet it is in metaphysics, not epistemology, that we will hit paydirt as we try and retrieve a suitably encompassing meaning for "relativistic".

VEDANTA AND OTHER ABSOLUTE IDEALISMS

It is fair to say that Stapp's final position resembles Berkeley and other idealists in that reality is conceived of as mental. This position was anticipated before Berkeley in Vedanta, which still commands a following in the West. Essentially, it argues – like Stapp – that reality is ultimately mental, with what we empirically experience as "mind" being just a container name for thoughts and similarly "the body" is essentially just sensations. This position was subscribed to by Schrödinger as he breathed in the same Irish air as Berkeley during his extended sojourn (1938-1955) in the Dublin he loved.

The "science and non-dualism" group in the USA has been led intellectually by Francis Lucille, a French physicist who like Stapp has interpreted von Neumann as legitimating idealism. More specifically, he stated that the union of Brahman and Atman can be operationalized as the statement that the wave function just before observation = the scientist about to observe. What von Neumann actually did prove is that the line between the two can be put at any point; Stapp has chosen to place pure consciousness on one side of this cut and quantum reality on the other.

It is now important to return to our TCP/IP of mentation. In this framework, such a realization may indeed prove true for noetic mentation at the final stage of the noumenal search, one in which even the relativistic perspective is encompassed in the ambivalence of subject and object that von Neumann established. This realization is not open to mentation at the sensorimotor and cognitive levels.

It is indeed not clear that "realization" is the correct word as such experience, if occurring, would be of a very austere, disincarnated type and, absent the quantum Zeno effect, occurring at a speed well above the relatively pedestrian sampling speed of consciousness in tenths of seconds.

The world, as we all know – occasionally to our cost – is decidedly not an illusion. We are often the objects of plans by others with different and perhaps hostile subjectivities. It will help them accomplish their plans if we become Vedantins. In fact, it is arguable that what even the most ardent Vedantin physicists do is import into their description of reality emotional and physical cathexes from the sensorimotor realm.

AUTO-EXOTICISM AND ITS DISCONTENTS; ON THE PROPER TREATMENT OF QM

Cultural theorists once, with some justification, excoriated the Irish for the sin of "Auto-exoticism". For example, they argued that Joyce's Ulysses was above all about a very typical small salesman hustling his way through a day in a very typical European city. That is not to say that QM is not in some ways a radical departure from classical physics. Entanglement, superposition, the uncertainty principle, and the mathematical operation of getting rid of terms not on the diagonal exemplify that QM, the most successful theory if the history of science, is indeed a brave new world.

This section is about how to handle in terms of the diversity of mind/world relations possible. First of all we keep hearing in both cognitive theory and quantum mechanics that the observer somehow creates reality. I would make the point that it does so in completely different ways. In constructivist theories like Piaget it learns about the world. In quantum mechanics the observer actually has a role in determining it. This has led to a return to a Berkeley-like absolute idealism in the work of Kafatos and Kastrup, claiming charter from Stapp (2017). For every Berkeley there is a Hume deflating the balloon, and leading to a radical empiricism. We may choose to avoid this.

We have introduced the following epistemological distinctions; sensorimotor, cognitive and noetic. Orthogonal to these are the metaphysical distinctions between "coupled " and "decoupled" with the latter submitting to finer grain analysis using terms like intentional, relativistic and noumenal as the split between subject and object becomes moot. In terms of this schema, observation in QM is noetic and noumenal, and – to borrow a term from Otto – the fact that this process can somehow determine external reality invites the term "numinous" as the essence of the sacred in Otto's work may be thought of as an unexpectedly sentient external reality.

For the moment, as my 2015 paper shows, mentation associated with QM can be construed of in terms of communication (instantaneous for entangled particles) and causality (none) with classical physical and biological reality differing systematically on these counts. As we have already established in this paper, the action of attention in observation causes a decorrelation of informational fluctuations in classical neuroscience very akin to getting rid of off-diagonal terms in QM. Finally, the 20 questions with nature in Stapp (2017) bears a striking resemblance to restriction of the domain in classical Q+A, and we will revisit this.

The problem is how to fit natural language into a schema that also can include quantum mechanics. There's something of a consensus about Bose Einstein condensates as being critical particularly if they are non-equilibrium. What Freeman did was with meticulous work point out how such a structure and process could come to exist in the brain.

Freeman didn't deal with symbols. Thought and language are in evolutionary terms completely different. Language is simply a formal system but thought biases the attractor surface in the brain. Now we come to quantum mechanics where what is effectively used is simply language as reality is not cognitively penetrable at that level. So instead of biasing attractor surfaces what has to happen is that there has to be a quantum field theory of the Cosmos itself. This was handled by people like Schwinger, as we saw.

It is possible – indeed, likely – that we are decades, if not centuries away from a conceptual structure that makes sense of QM. We have already seen that RIORQFT involves interaction with the wave function of the universe and Stapp (2017, 124-125) requires recourse to the Quantum zeno effect to transform the mental operations involved into something tractable in neuroscientific terms. Even then, the time involved at 10**-3 seconds is two orders of magnitude below the tenths of seconds typical of conscious experience.

Stapp's ontology is a mental monism. By contrast, Penrose's (1989) is a radical realism – he wishes to grant cognitive penetrability to the wave function at all stages – with a Platonic view of math. It is perhaps unfortunate that Penrose's U maps to Stapp's process 2, while the non-deterministic R maps to Stapp's process 1 as the order is inverted. It is also worth pointing out that, although an "objective reduction", Penrose's schema requires an intentional observer with a formal capacity >= standard arithmetic. The initial excitement of his approach was precisely due to its use of computability theory, non-recursive sets and admittedly naïve phenomenology and neuroscience.

Bohm's ontology, as interpreted by Sarfatti in our 2017 and 2018 collections, is recursive fibre bundles supporting an omniscient pilot wave – better thought of as a Qubit field - that probes the environment. The individual's act of mentation "writes onto" the pilot wave to give the experience of subjectivity. It is remarkable that Sarfatti – not known as a mystic – proposes exactly the kind of surrender of subjectivity to the infinite proposed in classical mysticism: "Not I, but Christ in me". Alternatively, as Hegel puts it in vol XX p206 line 26;"der Mensch 1st Anerkennen" (man is recognition /acknowledgement, the universe knowing itself through us). So no really individual acts of consciousness or selfhood exist here; they are grounded in the infinite.

The Sarfatti formalism is explicitly classical and deterministic, requiring a Lagrangian and thus not transcending Newtonian physics. At the cost of an omniscient, ubiquitous pilot wave we can allot definite position and momentum to particles. Given the ambition of his project – an informational framework in which subjectivity has a privileged role – his vaunted "solution" of the "hard problem" is thus worth taking seriously.

So which is correct? All, and none. They may turn out to be formally equivalent as happened before with the proof by Schrödinger, (1926) that his formalism was equivalent in Hilbert space to Heisenberg's matrix mechanics. Let us speculate a little.

Penrose is explicitly looking for a theory of quantum gravity and attempting to achieve objective reduction in a form "orchestrated" by quantum gravity – as distinct from doing so by other mechanisms like spontaneous localization. . Both Stapp and the Bohmians are after bigger game. Their act of noesis involves the wave function of the universe, or an equally universal pilot wave. Yet (personal communication) Stapp was astonished to hear that Zurek (1991, 2002) sees diagonalization of the matrix as the result of observation; he does not accept that this diagonalization is a result.

So what can we do? We have hints. The loss of off-diagonal terms in Penrose's R and after "nature's choice" seems indeed to point to something new under the sun and is the moment schisms from classical physics. It is the result of attention, as all would agree. Yet that is only part of the story. Even in classical neural firing, attention decorrelates informational fluctuations (Mitchell et al, 2009).

I now will cut to the chase. Let us first steady the telescope. The world is relative to our mentation in the manifold ways that this paper has tried to elucidate with the TCP/IP of mentation outlined. QM works at a point at which subject and object are physically labile in that the line between them can be drawn at any point. In the formulation here, it is the point at which the noetic enters the numinous.

There seems to be a consensus that, in the rarefied language of math in the noetic realm, observation in QM puts us in touch with the infinite and we can "alter" a reality that now indeed seems numinous. That does not alter the more prosaic facts of sensorimotor action, which remain as before and are being mastered by robots; or cognitive achievements at the highest level by AI , themselves a generation at most away. What remains is something infinitely more precious than mere cognitive competence.

The decorrelation found by Mitchell at al can occur independently of attention and is a mechanism used by sparsification of a signal by stellate neurons. Likewise, Zurek (2002) argues about diagonalization that the Joos (et al, 1985) prescription used by Stapp is inappropriate;

> "Moreover, we have obtained it—or so it appears—without having to appeal to von Neumann's nonunitary process 1 or anything else beyond the ordinary, unitary Schrödinger evolution. The preferred basis of the detector—or for that

matter, of any open quantum system—is selected by the dynamics. “.

For Stapp and Joos, much of the diagonalization occurs without process 1 and as a result of the observer before process 1 which then has flexibility to work in the vast areas in the matrix propinquant to the diagonal, allowing free will. . However, for Zurek, the very point of decoherence theory is to achieve this diagonalization without an observer. In his view of QM with observers – and here he disagrees with Stapp – process 1 creates the diagonalization.

This is not a disagreement with Stapp that (as distinct from Zurek) I am fomenting; it is rather an appeal to allow more facts be established before we come to any conclusions. Free will, remains robust, as indeed is a link with the wave function of the universe. It is remarkable how well it converges on the cosmic link to our actions with Sarfatti's utterly different formalism.

So we end with an appeal to the fact that through will, and the related bulwark of "downward causation", we humans seem to have to some extent mastered processes ubiquitous in nature. They include diagonalization in the quantum realm and decorrelation in the classical neural realm. These miracles are not a due to "pure mind" ontology; it is rather our ability to get in contact with the infinite, and in a very restricted noetic realm change the world. That is surely sympathetic to Henry's goal to reinstate meaningful human action.

CONCLUSION

The contrast between the dizzyingly wide scope of this paper and the simulations we called upon to buttress the argument is admittedly stark. The idea that individual neurons can perform a Fourier is radical enough for a whole lab for a decade. The idea that each language act is done in a domain which acts top down on neural process as a field will require in depth examination of attractor mechanisms in the brain using apparatus we do not have yet. Finally, the outstanding empirical success of QM - and in particular QFT – has not yet extended to any actual observation, as distinct from elegant and exciting ideas, of how these ideas cash out in neural structure and function. Or is noesis in any real sense "neural"?. This we hope to explore in Vitiello G and S. O'Nuallain (in preparation)

For the moment, our goals can be more modest. We can look at the contrast between symbolic and sensorimotor, and the orthogonal dimensions of coupled and decoupled architectures. The symbolic we will find to be exquisitely sensitive to context. From this basis, we can continue to develop computational systems that can move in real environments, and use these insights for computational systems that veridically use language. That done, we can with confidence proceed to the next stage of an appropriately sophisticated formalism of mind.

Finally, it has again become commonplace for physicists to postulate a grand scheme in which human mentation is seen as part of a nexus from an Absolute like a pilot wave to objects in the world. Some such schema may again prevail in the new space opened up by investment in quantum computing There will forever be tension between the debate over the capacity of the human mind that is posited as part of a system – often a recursive such system of fiber bundles – and the human mind which is assessing that capacity!

Foundationsofmind.org
seanoig@gmail.com

REFERENCES

Al-Khalili, J and J. McFadden (2014) Life on the edge London: Transworld

Asl, MM, A. Valizradeh, and P. Tass (2017) "Dendritic and axonal propagation delays determine emergent structures of neuronal networks with Plastic synapses " Scientific reports Jan 2017 DOI 10:1038/srep39682

Capolupo, Antonio, Walter J. Freeman, and Giuseppe Vitiello (2013) "Dissipation of 'dark energy' by cortex in knowledge retrieval " Phys Life Rev. 2013 March ; 10(1): 85–94. doi:10.1016/j.plrev.2013.01.001.

Craughwell, T. (ed.) (1998)Every eye beholds you. NY: Book of the month club Pp 258-261

Fox, M. (1991) Creation Spirituality SF: Harper

Freeman. W (1999)"How brains make up their minds" Ny: Weidenfeld and Nicholson

Freeman WJ (2003) "A neurobiological theory of meaning in Perception" Part 1: information and meaning. International journal of bifurcation and chaos.

Freeman WJ, Vitiello G. (2006) Nonlinear brain dynamics as macroscopic manifestation of underlying many-body dynamics. Phys of Life Reviews. 2006; 3:93–118.

Freeman, WJ.; Kozma, R.; Vitiello, G. (2012) Adaptation of the generalized Carnot cycle to describe thermodynamics of cerebral cortex. Proc IEEE World Congr Comp Intell WCCI/IJCNN 2012 Brisbane QLD; Australia. 10–15 June 2012;

IEEE Press; p. 3229-3236.
Freeman, W., S. O'Nuallain and J Rodriguez(2008) "Simulating cortical background electrocortigram at rest with filtered noise" Journal of integrated neuroscience, 7 (3) Page: 337 - 344 Sept 2008
Freeman WJ, Quian Quiroga R (2013) Imaging Brain Function with EEG: Advanced Temporal and Spatial imaging of Electroencephalographic Signals. NY: Springer
Freeman, WJ J. Integr. Neurosci., 13, 429 (2014).Book Review: "Karl H Pribram (2013) The Form Within: My Point of View"
DOI: http://dx.doi.org/10.1142/S0219635214800028
Fregnac, Y (2017)"Big data and the industrialization of neuroscience" Science, 358, 470-77
Houllebecq, M (2015) Sumission (surrender/Submission – translation by author)
France: Flammarion 69-70
Jacques, V. et al. (2008)Delayed-choice test of quantum complementarity with interfering single photons. Phys. Rev. Lett.100, 220402
Joos, E., and H. D. Zeh. 1985. The Emergence of Classical Properties Through Interaction with the Environment. Z. Phys. B 59: 223
Malinowski, B. (1954) Magic, Science, and Religion. NY: Doubleday
Mitchell, JF KA Sundberg, JH Reynolds (2009) " Spatial attention decorrelates intrinsic activity fluctuations in macaque area V4 " Neuron, 2009, 63. 879-888
O Nualláin, Seán "The Search for Mind" (Ablex, 1995; 2nd ed Intellect, 2002; Third edition Intellect, 2003;
Ó Nualláin, Seán (2004) "Being Human: the Search for Order" Second edition Exeter; Intellect, 2004;
Ó Nualláin, Seán (2000) "Spatial Cognition" (ed.) (Benjamins, 2000);
Ó Nualláin, Seán (1997) "Two Sciences of Mind" (principal co-editor) (Benjamins, 1997);
O Nualláin, Seán(2007) "Code and context" in Marcello Barbieri (ed.) "The codes of life" (Springer) Pp 347-356
O Nualláin, Seán (2008) "Subjects and Objects" Biosemiotics journal, Volume 2, Pp. 239-251
Ó Nualláin Seán (2013) "Neural Oscillations & Consciousness: Attention as a Litmus Test for the Quantum Mind Hypothesis" Journal of Consciousness Exploration & Research| July 2013 | Volume 4 | Issue 7 | pp. 697-713
Ó Nualláin, Seán (editor, 2017) "Foundations of Mind: neurodynamics meets QM" Proceedings of the 2017 conference at CIIS, preprint on cosmos and History

site (March 2017)

Ó Nualláin, Seán (editor, 2018) "Foundations of Mind: the new AI scare" Proceedings of the 2018 conference at CIIS, preprint on cosmos and History site (Jan 2018)

O Nualláin, Seán and T. Doris (2010) "What is neural resonance for?" Chaos and complexity letters 4(2)

Ó Nualláin Seán (2015) "Biosemiotics and the circle of explanation in the sciences" Quantum Biosystems 2015 Vol 6 Issue 1 Page172-180

O Nualláin, Seán (ed, 2016) "Foundations of Mind: homage to Walter Freeman" Proceedings of the 2016 conference at UC Berkeley, preprint on cosmos and History site (Nov 2016)

Penrose, R. (1989) The emperor's new mind. OUP.

Penrose, R. (2010) Cycles of Time. London: Bodley head

Reed, E (1997) From soul to mind New Haven, US: Yale UP

Roudinesco, E. (2018) "Overdose of cognitive and behavioral neuroscience" review of A. Ehrenberg "the mechanics of passions; brain, behaviour, society" Le monde Book section 13 April 2018. Translation by author

Sauvaget, B. (2018) "We are unfortunately living a return to the religious, not to the spiritual" Interview with Laurent Lemoine, Pp 20-21 Liberation 26-27 may 2018. Translation by author

Vitiello G and S. O'Nuallain (in preparation) QFT and neuroscience

Schrödinger, E., 1926, "On the Relation of the Heisenberg-Born-Jordan Quantum Mechanics and Mine", *Annalen der Physik*, 79: 734–756

Stapp, Henry (2017) "Quantum Theory and Free Will: How Mental Intent Translates into Bodily Action" (Springer, 2017)

Stewart, I (1990) Does god play Dice? Cambridge, Mass: Blackwell

Tegmark, M. (2000). "Importance of quantum decoherence in brain processes". *Physical Review E* **61** (4): 4194–4206. arXiv:quant-ph/9907009

Vitiello G (1995). Dissipation and memory capacity in the quantum brain model. Int J Mod Phys B. 1995; 9:973–989.

Vitiello, G (2001). My Double Unveiled. John Benjamins; Amsterdam: 2001.

Wheeler, J. A.(1978) Mathematical Foundations of Quantum Theory 9–48 (Academic Press)

Zurek, W. 1991. Decoherence and the Transition From Quantum to Classical. Phys. Today 44 (10): 36.

Zurek, W. (2002) "Decoherence and the Transition From Quantum to Classical. -revisited" Los Alamos science Nov 2002