

Chris Clarke

Being and Field Theory

Review Article

This article arises from the remarkably multi-faceted book *Brain and Being* edited by Gordon Globus and others, hereafter referred to as *B&B*.¹ It raises questions (though not unusually, few answers) about several related areas: the way in which quantum theory might endow the physical matter of the brain with surprising, though still essentially classical, properties; the possibility that quantum *field* theory might shed a wholly new light on aspects of consciousness, in both the subjective and neurological approaches; and, at the most speculative, the suggestion that the nature of being, as disclosed subjectively, can be understood in the light of one or other of the interpretations of quantum theory. I will consider these in turn.

1. The Emergence of Novel Behaviours for Matter

Many (for instance, Walker, Marshall, Penrose and Hameroff) have raised the possibility that the behaviour of matter in the brain is quantum mechanical; but the critical question must be asked, in what sense is ‘quantum mechanical’ meant? Trivially, quantum mechanics lies at the root of the behaviour of all matter; but beyond this two further claims can be made, of increasing strength. The more modest claim is that, when matter is organised on a hierarchy of length scales extending down to the molecular, then quantum effects induce long range correlations of molecular states, which in turn produce behaviour that is classically inexplicable and plays an important role in brain functioning. An interesting (though very idealised) example of how this might come about is discussed in this book by Jibu and Yasue (*B&B* pp. 267 ff), in which modifications of the ground states of long-range collective oscillations of molecules can form the basis for a system of distributed memory in the brain.

Correspondence: chris.clarke@scispirit.com

[1] **Gordon G. Globus, Karl H. Pribram and Giuseppe Vitiello (ed.)** *Brain and Being: At the Boundary Between Science, Philosophy, Language and Arts*, Amsterdam: John Benjamin Publishing Co., 2004, xii + 350 pp., €115.00, \$138.00, ISBN 90 272 5194 0.

The stronger claim, however, is that macroscopic correlated systems might literally be quantum objects in the sense of exhibiting quantum logic, so that the brain could in effect function as a quantum computer (Pribram, quoting Stapp, *B&B* p. 224). Both these claims require that a distinctive property called the *quantum phase* should be correlated from one point to another, in the presence of influences from the environment that tend to make it uncorrelated (a well investigated phenomenon called *decoherence*). But whereas the first claim involves only the modest requirement of the coherence of quantum phase *locally but continuously* throughout the whole of a connected system, the second claim raises much higher demands on the performance of quantum theory, by requiring the coherence of phase *globally* across the system. Hameroff and Penrose make a well defended, though still controversial, claim that this latter effect can occur at the level, intermediate between micro and macro, of the microtubules (with a less detailed claim that this behaviour can be ‘orchestrated’ globally); but most calculations would suggest that if quantum behaviour in this strong sense is to hold across physiologically defined regions of the brain, then some sort of addition is required to the conventional quantum formalism (as indeed is postulated by Penrose). These questions have stayed unresolved for many years: it appears that there are too many imponderables to decide them purely theoretically, and so it is gratifying to see in this volume a report of research by Fleischman (*B&B* pp. 241 ff) on artificial membranes, showing that coherence effects, possibly including the quantum phase, do hold between molecules of water at short length scales. This could start to bridge the gap between idealised theory and the real behaviour of cellular structures in the brain. We need much more of this.

2. The Role of Quantum Field Theory

(a) *The School of Umezawa*

Roughly nine of the papers in *B&B* stem from the work of the late Hiroomi Umezawa in quantum field theory, and most their authors insist that the effects of quantum processes in the brain can be derived only through the use of ‘quantum field theory’ (QFT), which they distinguish from ‘quantum mechanics’ (QM). I therefore need to explain this distinction. Both have the same broad structure. They are based on a space of *states* together with a space of *operators* acting on them and forming the basis for defining *observables*. Only this last category makes contact with actual laboratory physics, the states and operators in general remaining at the level of mathematical abstractions. Mathematically there is a fairly clear distinction between QFT and QT. In QT the operators are global objects, mostly themselves observables analogous to position and momentum, and the models correspond to systems with a finite number of degrees of freedom, such as those based on a fixed number of particles. In QFT, on the other hand, there are operators that vary continuously with position (hence the idea of ‘field’), corresponding to systems with an infinite number of degrees of freedom. Physically, however, the difference is far less clear cut, since most of the standard examples of QFT can equally well be seen either as the quantum analogue

of a theory of an unboundedly large number of particles (and thus as an obvious generalisation of QT), or alternatively as the quantum analogue of a classical field theory. These alternative accounts reflect, of course, the famous wave-particle duality.

As some of the authors concede, the effects being considered here can probably be grounded on a picture of the brain as made up of a finite (but very large) number of elements at different size-levels - either neurons (Takahashi and Jibu, *B&B* p. 301) or molecules (Fleischmann, *B&B* p. 241) – interacting through electrical forces that are classically conceived. In that case it should in principle be describable using QT. In practice, however, this might be impossibly complex, and so a field model, regarded as an ideal continuum limit, might provide a valid approximation that makes new conceptual tools available. But whereas a careful analysis of the validity of this approximation was made many years ago in the case of the Fröhlich quantum biological model (Duffield, 1988), the question of the validity of the field approximation is largely ignored in this volume. There is a feeling of the theoretical models floating in a void, neither grounded (as in the case of superconductivity research) in experimentation, nor in a study of the relevance of the mathematics to finite situations.

Many papers also rely heavily on a further aspect of QFT, namely the Nambu-Goldstone theorem that predicts the occurrence of massless particles (or quantised excitations sometimes called quasi-particles) when the field theory has a continuum of *different but equivalent* ground states (known as ‘vacuum’ states). Here the subject seems riddled with confusion, starting with Umezawa’s own introduction (Umezawa, 1993, p. 43) of a continuum of different vacuum states which he asserts are *inequivalent*, but using a drastically different definition of ‘equivalent’ from the conventional one used by Nambu and Goldstone! In this volume the equivalence of vacua for quasi-particle production is muddled with the inequivalence of vacua needed for phase changes, and ‘massless’ gets interpreted as meaning that ‘they do not add energy to the system’ (Frank, *B&B* p. 52), confusing rest mass and relativistic mass. It is an unimpressive spectacle.

(b) The Double

The brain is, of course, not an atom suspended in a void, but a system supported by a constant energy exchange with the rest of the body, and the rest of the world. It is, in technical jargon, a dissipative thermodynamic system, for which there has for a long time existed a well-trying extension of quantum theory to include thermal effects. Umezawa, however, introduces an alternative method which uses a modified form of the vacuum (in the above sense), derived by mixing the standard vacuum with the vacuum of a time-reversed copy (the ‘double’) of the system. His only justification for this seems to be the way it achieves an increase in the quantum fluctuations of states beyond that normally given by the uncertainty relations (Umezawa, 1993, p. 26), analogous to the fluctuations produced by heat. There is no indication that this approach models other aspects of thermal physics.

This has added a further layer of confusion to that which already surrounds quantum field theory. The idea of the double was publicised by Vitiello (2001), who here (*B&B* p. 319) reasonably explains that '[t]he doubled degrees of freedom ... are meant to represent the environment to which the brain is coupled'. His co-editor Globus (*B&B* p. 88) describes, however, the double as 'an alter universe that serves as a heat bath for our ... universe' in which resides the elusive 'subjectivity' of consciousness studies. 'We see now why we can never capture subjectivity, not because it is a different substance or a parallel process ... but because unreachable subjectivity is of an alter universe that defaults our own' (p. 93) — a suggestion that is firmly rejected by Vitiello (*B&B* p. 326).

3. *Being and Subjectivity*

Where, then, does all this leave the vexed problem of subjectivity, for which QT is so often appealed to for the solution? Other discussions of subjective awareness occupy a significant part of the book, but because of the above they sometimes rests on an unsure footing. There is nonetheless an important strand based on the idea that 'consciousness has primarily to do with the *presence* of phenomena, including of itself as a phenomenon (the phenomenon of self-consciousness), and far less to do with *thinking* ...' (Plotnitsky, *B&B* p. 35). 'Presence' is an *issue* in quantum theory, as opposed to classical theory in which the universe just baldly *is*. Franck (*B&B* p. 54), for example, argues that quantum theory implies a gradation from potentiality (in the sense of mere possibility), to the real-but-not-actual status of the quantum state, to the actuality that 'must take place when a memory state is selected for making appearance in mental presence.' He helpfully links this with Heidegger's account of presence in *Being and Time*. The association of consciousness with (some forms of) memory-recording is an established part of many schools of cognitive science (e.g. Barnard, 2004), and the discussions here suggest that at least the *language* of QT can play a role in clarifying confusions that seem built into the language of the everyday. In these considerations it is not merely that, as in the well known caricature, subjectivity is mysterious, quantum theory is mysterious, so they must be connected. It is that, if further research shows that both mysteries do converge in the biological phenomenon of consciousness, then this gives an indication that they are in fact the *same* mystery, on which a two-fronted attack may then be possible.

The volume is also valuable for its inclusion of an approach to subjectivity, at first sight quite different, via the concepts of information and meaning. One formulation of the problem of consciousness is the need to explicate intentionality, the way in which a neural state comes to *mean* an external object. Both Hiley (*B&B* p.209) and Pribram (p. 235), develop this from Bohm's (1985) ideas of a duality between 'soma' (literally, body), the manifest aspect of a process, and 'significance', the 'subtle' aspect woven beneath the surface. The novelty of Bohm's insight was that this did not reflect a fundamental duality in nature between fixed realms of mind and matter (a concept that hovers around Umezawa's 'double'), but rather the different views of a single process from two

different levels of an indefinitely extended hierarchy of manifestation. 'Content' and 'context' are another conceptualisation of the same duality, in which the context of one level can itself become the content of a higher level. At the smallest level this becomes the context-dependence of Bohr's interpretation of quantum theory. Thus 'mind and matter [are] two aspects of one undivided process'. This does not solve the problems but does make way for the solution that Bohm started to sketch, through his consideration of differing aspects of the first-person perspective where we humans live our lives.

References

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