Quantum Mechanics and Consciousness: A Causal Correspondence Theory

I.J. Thompson

Physics Department, University of Surrey,
Guildford GU2 5XH, England

17 October 1990

Abstract

We may suspect that quantum mechanics and consciousness are related, but the details are not at all clear. In this paper, I suggest how the mind and brain might fit together intimately while still maintaining distinct identities. The connection is based on the correspondence of similar functions in both the mind and the quantum-mechanical brain.

1 The Mind-Brain Problem

The problem of the relation between mind and body is well known as a difficult 'world knot'. Over the centuries various monistic and dualistic theories have been proposed, and the subject has had renewed interest as we try to assimilate the implications of quantum physics. These implications may make us reexamine our views of brains and bodies, but it is still not clear what consequences they have for our understanding of minds.

Earlier in the interpretation of quantum mechanics, it appeared that the problem of *measurement* could only be solved by introducing some basic notion of an *observer*, presumably a conscious observer. Many scientists and philosophers (e.g. Wigner[20], Popper[6], Faber[8], Toben[18], Squires[14], Donald[5] among others) have taken this solution to indicate an essential role of consciousness in the physical world. Consciousness, to solve the measurement problem, must initiate the transition from quantum potentialities to definite actualities. It would not have to select *which* actuality, but merely cause *some* actuality to be produced. Squires and Donald accept this merely 'collapse prompting' role of consciousness, and their position has the advantage of requiring no changes to quantum theory, as consciousness then makes no change to any predicted probability. Squire's

conclusion, unfortunately, does not yield any functional role which may be important in mental and/or physiological processes in the brain. Donald[5] does go on to give circumstances in which 'measurement collapses' are important for the function of neural cells, but their effects are simply to reinstate the 'classical' on/off nature of the sodium switches even when there are quantum uncertainties.

Since, moreover, it is possible that the 'measurement problem' can be solved within physics (see e.g. Maxwell[13]), the role of consciousness in measurement has little direct bearing on the problem of how the mind and brain *function* together. In order to say something relevant to the brain sciences, we have to go beyond conventional quantum mechanics (of whatever interpretation), and make new hypotheses with definite empirical content. We have to postulate that 'consciousness' (whatever that may turn out to be) influences the actual outcome of neural events, and does not just observe them as if disinterestedly.

2 Quantum Brains

It is well known that there is a residual indeterminism of quantum mechanics in making predictions of physical processes. Quantum mechanics is also 'non-local', as described for example by Bell's inequalities. If either of these two phenomena are displayed in the brain as described by quantum physics, then this may be relevant to the problem of consciousness.

Biased Probabilities: One proposal (from Walker[19] and later Eccles[6]) has been that mental events influence at least some physical outcomes within the range allowed by quantum mechanics. This idea has to supplemented by an account of how these small effects are amplified to affect macroscopic outcomes, and recently possible accounts have been presented[7]. Eccles requires that the options of a single vesicle discharging or not discharging both have non-zero quantum probabilities, so that such neural events are genuinely under-determined by quantum mechanics, and the way is open for them to be determined by the mind.

Bose-Einstein Condensates: Another proposal by Marshall[12] is that the mental and bodily realms derive directly from a quantum realm, as separate appearances of an underlying structure given by quantum mechanics. Since the *unity* of mental experience is one of its outstanding features, the proposal is that consciousness arises from a quantum mechanical structure which shows remarkably unity, namely Bose-Einstein condensates. This therefore requires not only that the brain amplifies quantum indeterminism, but also that long-range and long-time correlations of quantum phases are set up in the brain, by means for example of a structure proposed by Fröhlich.

Both these proposals go some way toward connecting the apparently disparate realms of mind and brain. From the physics side, both have quantum mechanics holding virtually unchanged. They furthermore then both require that neurophysiological processes are in some essential way 'quantum processes'. They require then that the peculiarly quantum features of matter become much more spatially spread out in the brain than is usually admitted. In the language of physics, Marshall requires that non-local correlations (of the kind described by Bell's Inequalities) are set up between parts of the brain that are very far apart on the atomic scale, and hence that the brain exhibits some of the characteristics of 'quantum computers' as described by Deutsch[4]. There is a difficulty that this implies much larger quantum effects than have ever been observed in materials at room temperature. There is evidence of unusual microwave absorption, but it is not clear whether this really demonstrates quantum correlations as distinct from sets of coupled classical (non-quantum) oscillations.

Eccles' proposal is weaker than Marshall's, as he only requires that for some brief time the non-local correlations extend between the options of a single vesicle discharging or not discharging, so there can exist a coherent superposition of these two states. Eccles does not require that the two options remain coherent for any duration after the event (as Marshall would require to obtain widespread and persisting quantum phase coherences).

Both proposals are made less likely by the fact that Plank's constant ($\hbar$), the constant which sets the scale for quantum processes, is so small. It is not impossible that there are genuinely undetermined neural events in the brain, and/or that there are large scale quantum coherent effects, but these are difficult to set up in the noisy room-temperature non-crystalline system of the brain.

Psychological Considerations

There are also questions from the psychological point of view. Eccles' proposal tells us very little about the structure of the mind, apart from the fact that it must be able to predict and control the amazingly complicated system of many of the random discharges in the brain. There is little indication from what psychologists know about the mind that it has anything like the required analytical and motor capacities. The mind is best dealing with at most 5 to 8 items, and is completely swamped when it tries to understand massively parallel systems directly. A way of avoiding these difficulties will be discussed below in §3.5.

Marshall's proposal seems to tell us more about the mind, namely that it arises whenever quantum mechanics gives suitable Bose-Einstein condensates. However, all psychological details of mental structure and operations would then be derived from this quantum structure. That is, he would have to claim that all human life (from mathematics and logic to arts to psychopathology) is implicit in Schrödinger's equation. Personally, I find it extremely implausible that the quantum mechanics of patterns of excitations of Bose-Einstein condensates ex-

actly and mechanically determines the interaction patterns of ideas, images and meanings in the human mind. There are certainly *similarities* between the two, but these do not imply identity. To talk of similarity without giving evidence for identity leads to another approach, as we see next.

3 A Different Approach

Despite the apparently smallness of quantum effects in the brain, I still believe that quantum physics is important in our understanding of its function. To show this, I am going to take a different approach. I am going to assume, in a non-reductionist way, as Eccles and others do, that the mind is (in some way) distinct from the brain. But I want to then see how they could be intimately connected again[1].

I am going to take a 'top–down' to the problem of interaction, and will suggest how it may usefully be organised, from the functional point of view. I am not going to assume that quantum mechanics must be unchanged; I am therefore going to follow the 'spirit' if not the 'letter' of quantum physics. The aim is to motivate a plausible general view which will make predictions about what goes on. Afterwards I will discuss the origins of this general view.

The guiding principle I use is that the mind and brain are similar in structure and function, and that they need each other to operate. They are not identical, but are *similar* in the sense of 'resonating' or 'corresponding' to each other from the functional point of view. In order to see *how* the mind and brain are similar and fit together in this general way, we do need to remember quantum physics.

3.1 Similarity of Minds and (Quantum) Brains

I am here going to draw analogies between mental and quantum phenomena[2]. Some of these have been pointed out by Bohm[2, §8.27ff] and more recently by Jahn & Dunne[11] and Zohar[21] (although perhaps understood in different ways: see later discussion).

Jahn and Zohar have tended to concentrate on the analogies between mental structures, and the structure of matter entailed by quantum mechanics. They look at analogies between, for example, minds and quantum systems, and then especially analogies between how minds interact and how quantum systems interact. I will be looking rather at analogies between *individual* mental processes within minds and individual quantum processes. I believe that only when we

[1] Psychologists and psychiatrists are aware of the close functional dependence of minds and brains, so that physiological changes very readily affect the mind in many ways, and mental intentions and attitudes affect both the normal and abnormal functioning of the nervous system.

[2] If you already know something about minds, these may help you understand quantum physics!

understand the elementary processes of both the mind and quantum matter, can we more completely understand complex systems of either kind.

In order to make analogies with quantum physics, I am going to assume something like the 'propensity interpretation' of Maxwell[13] and others[15]. I am also going to assume a view of mind that is in part phenomenological (after Bergson especially), and in part influenced by (a few of) the aims of artificial intelligence (AI) and the recognition of the complexity of even apparently elementary mental processes. On this basis, we can draw analogies between the fundamental processes of quantum physics and the fundamental processes of mental activity:

- Quantum objects do not evolve uniformly in time, but as a succession of 'states' between intermittently 'actualising' to one outcome of a certain range.

  Mental entities do not evolve uniformly in time, but in a succession of 'specious presents' between intermittent changes of state.

- The state of a quantum object is not a static configuration of elements, but a 'state of propensity' for possible virtual proceses, possible interactions and possible actual (observable) outcomes.

  The state of a mind is not static, but more a 'state of propensity': it is a continual recollection of past events and continual anticipation of future possibilities.

- The state of a quantum object may be described by a wave function distributed is space, but this does not mean that the quantum object is composed of elements so distributed. Rather, it has a basic unity in that it will always act as a whole. These spatial distributions merely describe where it *can* actualise.

  The state of a mind has a similar basic unity. The thoughts in the mind may be diverse, and each may implicitly contain diverse elements (usually the better for doing so), but if they lead to action these diverse elements were merely describing where the mind *could* have operated.

- The driving impetus of quantum processes are not external, but the very propensities of which quantum objects are forms. These propensities operate according to the (spatiotemporal) circumstantial relations with other objects.

  The driving motivation of mental processes are not external, but the very motivational loves which underly all psychic activities. These motivations operate according to the circumstances at each time.

- Behind the apparently continuous evolution of the Schrödinger's equation, there is a progressive multitude of 'virtual events' whose operation forms the potential term in Schrödinger's equation.

> As a consequence of simulation efforts in AI, we know that the operation of even seemingly simple events such as the perception of solid objects must involve 'behind the scenes' a great deal of information processing which is not apparent in the act of perception itself.

In view of these analogies, and also those given later in §3.4, it unlikely that the mental and physical processes are independent, and merely interact with each other at certain 'mental-neural' events[7]. We could hold that they both derive from a 'quantum realm', but I hold to a more radical (but simpler) idea that *the propensities for physical processes derive from mental processes, which in turn always act according to past physical events.* This idea, explained further in the next section, means that the mental and physical realms are far from separable, but are intimately related in a very systematic manner. Thus, although the basic idea may not be exactly fashionable these days, it is an idea with significant predictive power and good empirical content.

3.2 How Minds and (Quantum) Brains Fit Together

In order for people to have functioning minds, their minds must at least be able to

- implement intended functions using the motor areas,
- establish permanent memories, presumably by means of permanent physiological changes,
- form perceptions using information from the visual & auditory (etc.) cortexes,
- be able to follow 'internal' trains of thought/feeling/imagining without necessarily having any external effects.

One way that these requirements can be most simply accomplished is by means of the idea above, formulated in the following three principles:

I. That the mind predisposes the physical/physiological potentialities (both deterministic or indeterministic according to quantum physics).

II. That the 'predispositional' capacities of the mind are consequentially restricted (and hence conditioned) by their actual effect.

III. That the pattern of I and II is repeated for individual stages of more complex processes.

These principles together give what can be called 'conditional forward causation', or 'top-down causation'. Note that we do *not* have a fourth 'bottom-up' principle that neural events directly cause events to occur in the mind. We do not have general matter → mind causation, although something resembling this does arise, namely 'selection'. This is not causation in the primary sense of 'principal causation' as 'producing or generating the effect'. It is more in the secondary sense of 'instrumental causation' as 'providing a necessary prerequisite'.

A strong argument for these three principles is that they are already similar to what is known already to happen in quantum physics, in quantum field theory to be precise. According to that theory, there is a class of events called 'virtual events' which select and predispose the ordinary quantum wave function. These virtual events operate deterministically, and describe the operation of the electric, magnetic, nuclear and gravitational forces. They are not the 'final' actual events of quantum mechanics (those are the definite outcomes of events like observations). Rather, they are a 'prior level' of 'implicit events' whose operation is needed in order to produce the potentialities for events like observations. The principle (I) states the analogical result that mental events themselves are a 'prior level' of 'implicit events' whose operation is needed in order to produce the potentialities for physical events.

The argument for the principle (II) is more general. Whenever *any* potentiality is exercised to produce a particular outcome, future potentialities must depend on the detailed outcome. Suppose for example that at the moment, I have the potentialities of moving left or right; if I actually move left, say, then this influences (by restriction to a fixed history) of what I can do from now on. This second principle can also be seen as a 'law of karma': your future life is restricted and influenced by your past actions (by selection). Physical events are in this way the necessary foundations for permanent mental history and structure.

Principle (III) has an important corollary

IIIb. That the mind predisposes the brain to carry out those functions which 'mirror' or 'correspond to' the mind's own functions.

This is because mental functions involve intermediate steps, and these intermediate mental steps predispose suitable intermediate physical steps (by I), and are in turn conditioned or confirmed by them (by II). Thus the sequence of physical steps will follow the sequence of mental steps, and the overall function of the physical process will be analogous (in some sense) to the overall function of the mental process. Examples of this 'mirroring' or 'corresponding' have already been illustrated by the similarities between minds and brains listed in the previous section. Examples of correspondences of complex processes in the mind with those of physics will be given below in §3.4.1.

Let us then see how these principles enable the mind and brain to function together:

- The particular functions selected by the mind to be carried out by the brain will be the establishment of spatiotemporal patterns of neural activity that may then be 'decoded' in the motor cortex to lead to the desired activities, by the principle (I). Principle (IIIb) establishes a criterion for the overall functioning of this decoding.

- Permanent physiological changes lead to permanent memories in the mind, by the principle (II). (It is an empirical question, *which* physiological changes are relevant, but principle (IIIb) will be a guide.)

- Perceptions are formed by the sensory cortex areas deterministically forming particular patterns of neural activity, so that these physiological effects can select the subsequent perceptual content of the mind. The process here is rather subtle. The mind must have a 'general disposition' to see/imagine any of its possible percepts; the role of the sensory cortex is to *select* the particular content, by means of principle (II). Thus we have the general psychological observation that 'we see only what we are capable of and disposed to see'.

- To be able to follow 'internal' trains of thought/feeling/imagining without necessarily having any external effects, the mind must be able to produce physiological effects which do not have any significant consequences. Presumably, much of the cerebral cortex can function in a 'loosely connected' way, in order to provide the foundation for a set of permanent mental structures.

3.3 Mind and Brain as 'Hand and Glove'

This theory of mind and brain connection establishes in intimate relation between them. It is not a relation of identity, or a relation of aspects or points of view. It is more a relation of inner and outer, or cause and effect: propensities in the brain are the causal product of mental actions. As put in ref. [1], 'the role of the psychical in relation to the physical (in the living organism) is essentially the relation of the potential or incipient to kinetic or overt action'.

The mind and brain fit together by approximate analogy with hand and glove, or, better, with tissue and skin. The analogy (by principle IIIb) is most precisely with the *functions* of tissue & skin, and not so much with their material shape. The mind provides all the directed activity of the brain, just as the tissue of the hand provides all the directed activity of the skin of the hand. When we look at the head, we only see the brain, just as we only see skin when we look at the hand. It *appears* that the skin of the hand does all the work, but we don't assume that that is all there is. It *appears* that the skin has life, but we know that all but the simplest life comes from the underlying tissue. The skin (as does the brain) has simple capacities for action and reactions, but it is a mistake to imagine that

Net Level	Network Relations of	Developed in Piaget/Gowan Stage	during ages
5	meta-theories, paradigms	creative	17–
4	plans, models, formalisms	formal	12–16
3	classes, series, numbers	operational	7 –11
2	events, single relations, sentences	preoperational (preconceptual & intuitive)	2 – 6
1	objects	sensorimotor	0 – 1
0	images, motor movements	(initial)	– 0

Table 1: **Relation between Network Layers and Piagetian Stages** During each stage, at the approximate ages shown, the child is learning to relate the concepts listed in the second column. That is, he is constructing relations in a network at the given level.

all capacities for activity and information processing belong to the skin (or the brain).

3.4 Psychology

Once we have the basic idea of functional correspondences between physical and mental systems based on their causal interrelations, then we have a fertile source for exploring the detailed structure of one using what we know about the other.

3.4.1 Psychology of Stages

Because there are 'prior' and 'post' levels of events even *within* physics, by the correspondence principle IIIb, there must also be prior and post levels of events within the mind. Piaget's theory of stages of development is relevant here. In table 1 the Piagetian stages have been reformulated as the acquisition of capacities for dealing with ideas on the successive layers (supplemented by a 'creative stage' of Gowan[9]: see ref. [17] for more details). The relations between the ideas of adjacent levels is then analogous to the relation between any pair of prior and post events, according to principles I, II and III above.

There appears to be a broad analogy of the 'practical' layers (0, 1 and 2) with the 'real' events of quantum mechanics, and of the 'theoretical' layers (3, 4 and 5) with its 'virtual' events. This can be spelt out in more detail, approximately as in table 2. Here, the basic idea (following principle IIIb) is that the mind at a given stage is capable of 'thinking about' the corresponding features of quantum mechanics. The set of propensities/quantum systems/actual selections provides the mechanisms for the actual events of ordinary (non-relativistic) quantum mechanics, whereas the set of least-action principles/evolution equations/groups describes the basic principles and virtual events of quantum field

Net Level	Network Relations	Quantum theory
5	meta-theories, paradigms	least-action principles
4	plans, models, formalisms	time evolution equations
3	classes, series, numbers	invariance groups
2	events, single relations	propensities
1	objects	quantum systems
0	images	actual selections

Table 2: **Relation of Network Layers to Quantum processes**

theory.

3.4.2 Artificial Intelligence and Neural Networks

Neural networks have proved to be useful framework for formulating a wide range of information processing problems in cognitive psychology. This has lead some to postulate their sufficiency for a system of artificial intelligence. However, there are three main problems with neural networks. The first is the question of speed, the second the problem of procedures, and the third the problem of levels.

1. In order for neural networks to (approximately) solve global optimisation problems, some search procedure such as simulated annealing is required. This is notoriously slow, and, as still a procedure of 'exponential complexity', will be prohibitively slow for problems of realistic complexities.

2. Neural networks have fixed connections only, and in order for them to achieve anything like translation or scale invariances for perception, then all possible translations and scales have to be 'hard wired' simultaneously [10]. This could be avoided again by some 'procedural' or 'algorithmic' mechanisms, with 'variable bindings', but this can only be implemented in neural networks by 'brute force' multiple connections.

3. Neural networks seem to plausibly describe the interactions of related ideas on a given 'level' of table 1. They are notoriously poor, indeed AI as a whole is notoriously poor, at modelling the connections *between* the separate layers (see [17]).

It is still possible that the brain uses neural networks so that their various 'final states' serve to indicate different image categories and different actions. In the present causal theory of mind-brain interaction, however, it is more likely that the mind can act by predisposing the neural nets to settle to some preferred outcome. That is, the mind determines (from the function it wishes performed) which collective state of the neural system is to be achieved. From the point of view of the brain, the neural net would appear to be the 'non-deterministic

automaton' of complexity theory, heading more or less quickly for the preferred solution (while thus verifying that it *is* a solution).

The problems of procedures and levels in neural networks are resolved by having multiple levels of simultaneous mental operation *within* the mind. The relations between the multiple levels then follows the principles I, II and III. Principle I means that the higher level predisposes the interactions at the lower level. Principle IIIb means that it does so in order to carry out particular functions. Principle II means that configurations at the lower level (e.g. images) select a particular perception (e.g. of an object) which would produce that image. This selection must be able to made very quickly — much more quickly than any detailed analytical algorithm could be elaborated.

3.5 New Physics

What is new physics in this proposal, is the first principle I: that the mind predisposes the physiological potentialities (whether deterministic or indeterministic according to quantum physics). This relation between mind and brain is analogous to that between virtual and real quantum events, but postulating the mind/brain relation to be of this kind has new empirical content.

The predisposition of physical propensities is of course not arbitrary. It is conditioned from the physical side by past actual events, from the mental side by the functions which may be accomplished, and from both sides by the requirement of correspondence. These constraints mean we do not have merely a 'mind of the gaps' which fills in what is left undetermined by modern science. There are certainly gaps to be filled, but the present scheme will also explain what we already know, not just what we don't know.

If, for example, there is a regular sequence of actual physical events, and the predisposition is not varying, then there will be a constant production of new propensities, and hence a regular sequence of physical effects as if by a universal physical law. Thus our principles can provide a new basis for physical laws which we already know.

When there are intermediate propensities (e.g. of individual minds) then physical events do not follow the previous simple pattern. The new pattern will describe how the brain works in conjunction with the mind. Clues to this behaviour can be found by analogy with psychological processes, as discussed in §3.4.1.

- We saw in table 2 that the images (in the mind) correspond to actual selections (in quantum mechanics). This casts new light on our old problem of the role of consciousness in quantum measurement, and we see that perception of images does cause and correspond to the selection of actual outcomes of measurement in quantum physics. It is similar to Eccles' proposal, but now we have a better idea of the mental side of the picture. The network

level 0 is the initial stage of cognitive development, and does not require any sophisticated analytical or predictive capacities: it is more the ability to 'see what there is to see'. This means that the selection of outcomes of measurements does not happen at the time of the (random) event, but later, when *perceptible* differences have emerged, *and are perceived*.

- The ability of the sensorimotor mind to influence the course of events is, however, quite limited. Its role in everyday life is more to provide a source of perceptions, and implement outcomes that have already been decided. This corresponds in quantum mechanics to the small size of Planck's constant, and the rarity of quantum-random events which *do* have perceptible differences. Occasionally, however, there is still a need for basic decisions, and (in the mind and in quantum mechanics) it is necessary to decide between one of a small number of options. On these occasions, consciousness does limit itself to a single perception, and this does cause the selection of a particular outcome of a event left random by quantum physics.

- Most of the interesting processes in the mind and in quantum physics take place at levels 3 – 5: the 'theoretical' layers as these were described earlier. Processes occur at these layers which generate in the first place the 'short list' of options for the sensorimotor mind, and a great deal of detailed knowledge and derivation goes into this preparation.

- The operation of predisposition and correspondence in these 'higher' levels must mean that the time-evolution equation of physics, normally taken to be Schrödinger's equation, is not fixed. We should be able to discover circumstances in which even classical systems follow a modified physical law.

3.6 'New' Metaphysics

These ideas have the possible disadvantage (or feature) that the operation of ordinary inert physical processes requires further analysis. Basically, since the propensities for physical processes derive from mental processes, all physical dispositions must derive (or have been derived from) some prior psychical level. This may sound like pan-psychism, but I am not saying that all physical processes include their *own* consciousnesses. There is a simpler solution, if you can accept the new metaphysics that there is some kind of Source, composed of suitable 'psychic' propensities, from which everyday material propensities perpetually derive. Since the operation of this Source is always according to past physical events, we saw above that this operation amounts to the constant production of new propensities as if a 'physical law' were prevailing. That is the way most scientists prefer to see the world. It is only that sometimes things are not so simple.

There may be some reaction to the apparent 'dualism' in these ideas, as I have postulated minds existing separately from brains. However, this separation is only in our theory: in practice they need each other, and function together as a unified whole — as the person.

3.7 Origin of these ideas

I have presented these ideas as worth of consideration on their own, but they really have a long history in a variety of contexts. The basic idea that causation only truly works from the mind into the brain (and not vice versa) is not a popular one today, but has to be traced back to 'non-standard' insights of people such as Plotinus (b. 205), Boehme (b. 1575), Swedenborg (b. 1688) and some other traditions. Swedenborg was well educated as a physicist and then physiologist, so I find his accounts the most detailed and useful. Of course, he knew nothing of quantum mechanics (only Newtonian mechanics), so I have had to 're-apply' his principles in the light of what we now know about the physical world. He, however, has the clearest presentation of the idea of 'conditional forward causation' (he calls it 'influx into uses'), and he gives the most complete account of the 'correspondences' which exist between mental and bodily things. For a brief summary of his ideas, see my ref. [16].

4 Conclusion

In order to understand how the mind and brain function together, it is not enough for there to be gaps in our physical theories. We also need to have a unified picture of both minds and brains. In this paper I have tried to outline such a unified approach. These suggestions require some departure from what is commonly accepted in the physical sciences, but we can still learn a great deal from what has already been discovered both there and in the psychological sciences.

References

[1] Bawden, H.H. 'The Psychical as a Biological Directive', *Philos. Science*, **XIV** (1947), pp. 56 – 67.

[2] Bohm, D. 'Quantum Theory', Prentice-Hall (1951).

[3] Bohm, D. 'Wholeness and the Implicate Order', Routledge and Kegan-Paul (1980).

[4] Deutsch, D. 'Quantum Theory, the Church-Turing principle and the universal quantum computer', *Proc. R. Soc. Lond*, **A 400** (1985), pp. 91 – 117.

[5] Donald, M.J. 'Quantum Theory and the Brain', *Proc. R. Soc. Lond*, **A 427** (1990), pp. 43 – 93.

[6] Eccles, J. and K.R. Popper, 'The Self and Its Brain', Springer (1977).

[7] Eccles, J. 'Evolution of the Brain: Creation of the Self', Routledge (1989).

[8] Faber, R.J. 'Clockwork Garden', (1986).

[9] Gowan, J.C. 'Development of the Creative Individual', Knapp (1972).

[10] Hinton, G.E. and K.J. Lang 'Shape Recognition and Illusory Conjunctions', *Proceedings of IJCAI-85*, (1985) pp. 252 – 259.

[11] Jahn, R.G and B.J. Dunne 'On the Quantum Mechanics of Consciousness, with Application to Anomalous Phenomena', *Foundations of Physics*, **16** (1986) pp. 721 – 772.

[12] Marshall, I.N. 'Consciousness and Bose-Einstein Condensates', *New Ideas in Psychology*, **7** (1989) pp. 73 – 85.

[13] Maxwell, N. 'Quantum Propensiton Theory: A testable resolution of the wave-particle dilemma', *The British Journal for the Philosophy of Science*, **39** (1988) pp. 1 – 50.

[14] Squires, E.J. 'An Attempt to Understand the Many-worlds Interpretation of Quantum Theory', in *Quantum Theory without Reduction*, ed. Cini and Levy-Blond, Adam Hilger (1990), pp. 151 – 160.

[15] Thompson, I.J. 'Real Dispositions in the Physical World', *The British Journal for the Philosophy of Science*, **39** (1988), pp. 67 – 79.

[16] Thompson, I.J. 'Swedenborg and Modern Science', *Scientific and Medical Network Newsletter*, **26** (1989) pp. 3 – 8.

[17] Thompson, I.J. 'Layers of Semantic Nets and Developmental Psychology', unpublished.

[18] Toben, B. 'Space-Time and Beyond', Dutton (1974).

[19] Walker, E.H. 'The Nature of Consciousness', *Mathematical Biosciences*, **7** (1970), pp. 131 – 178.

[20] Wigner, E. 'Remarks on the Mind-Body Question', pp. 284 - 302 in *The Scientist Speculates*, I.J. Good, ed: Basic Books, N.Y. (1962).

[21] Zohar, D. 'The Quantum Self', Bloomsbury (1990).