5. The Eccles-Beck Approach.

Sir John Eccles suggested in 1990, in the Proceedings of the Royal Society (Eccles 1990), that quantum theory plays a key role in the workings of the conscious brain. Based in part on his discussions with Henry Margenau (See Margenau 1984), Eccles noted that the statistical element in quantum theory allows an escape from the rigid determinism of classical physics that has plagued philosophy since the time of Isaac Newton. In his later book “How the self controls its Brain” Eccles (1994) notes that , “There is of course an entrenched materialist orthodoxy, both philosophic and scientific, that rises to defend its dogmas with a self-righteousness scarcely equaled in the ancient days of religious dogmatism.” He says at the outset that, “Following Popper (1968) I can say:

I wish to confess, however, at the very beginning, that I am a realist: I suggest somewhat like a naïve realist that there is a physical world and a world of states of consciousness, and that these two interact.”

Eccles gives “two most weighty reasons” for rejecting the classical-physics-based concept of materialism. (Eccles 1994, p,9) First, classical physics does not entail the existence or emergence of the defining characteristic of consciousness, namely “feelings,” and hence entails no theory of consciousness. Second, because the nature of the mapping between brain states and states of consciousness never enters into the behavior of an organism, there is no evolutionary reason for consciousness to be closely connected to behavior, which it clearly is.

Eccles’ approach to the mind-brain problem has three main points. The first is that consciousness is composed of elemental mental units called psychons, and that each psychon is associated with the activation of a corresponding macroscopic physical structure in the cerebral cortex that Eccles calls a *dendron*. It is anatomically defined, and is connected to the rest of the brain via a large number of synapses.

The second point is the claim that quantum theory enters brain dynamics in connection with exocytosis, which is the release of the contents of a “vesicle” – filled with neurotransmitter – from a nerve terminal into a synaptic cleft.

The third point is a model developed by the physicist Friedrich Beck that describes the quantum mechanical details of the process of exocytosis.

The first claim, that psychological processes have elemental units associated with dendrons, places Eccles’ theory somewhat apart from those who have suggested that *the electromagnetic field* in the brain might server as the carrier of the physical correlate of consciousness. (Taylor 2002, McFadden 2002, Pockett 2002, Pockett 2000, Stapp 1987, Stapp 1985) Evidence for the electromagnetic hypothesis has been presented particularly by McFadden. However, the very close causal connection between the activation of a dendron and the activation of an electromagnetic field in the neighborhood of that dendron makes these two proposals difficult to distinguish, empirically.

More germane to our topic is the second component of Eccles’ proposal, which is that quantum effects enter importantly into brain dynamics in connection with cerebral exocytosis. This is a very plausible, and indeed inescapable, conclusion. Exocytosis is instigated by an action potential pulse that triggers an influx of calcium ions through ion channels into a nerve terminal. These calcium ions migrate from the ion-channel exits to sites on or near the vesicles, where they trigger the release of the contents of the vesicle into the synaptic cleft. The diameter of the ion channel through which the calcium ion enters the nerve terminal is very small, less than a nanometer, and this creates, in accordance with the Heisenberg uncertainty principle, a correspondingly large uncertainly in the direction of the motion of the ion. That means that the quantum wave packet that describes the location of the ion spreads, during its travel from ion channel to trigger site, to a size much larger than the trigger site (Stapp 1993/2003.) That means that the issue of whether or not the calcium ion (in combination with other calcium ions) produces an exocytosis is a quantum question that is basically similar to the question of whether or not a quantum particle will pass through one or the other slit of a double-slit experiment. According to quantum theory the answer is ‘both’: until the brain process reaches the level of organization corresponding to the occurrence of a Process I action one must retain *all* of the possibilities generated by the Schroedinger equation, Process **2**. In particular, one must retain both the possibility that the ion activates the trigger, and the exocytosis occurs, and also the possibility that the ion misses the trigger site, and the exocytosis does not occur.

For cortical nerve terminals the observed fraction of action potential pulses that result in exocytosis is considerably less than 100%. This can be modeled classically. (Fogelson 1985.) But the large Heisenberg uncertainty in the locations of the triggering calcium ions, entails that the classical uncertainties will carry over to similar quantum uncertainties, and the two possibilities at each synapse, 'exocytosis' and 'no exocytosis', will, prior to the occurrence of the Process **1** or Process **3** actions, *both be present* in the quantum state S(t). If N such synaptic events occur in the brain during some interval of time in which no Process **1** or **3** events occur, then the state S(t) of the brain will evolve during that interval into a form that contains (at least) 2^N contributions, one for each alternative possible combinations of the 'exocytosis' and 'no exocytosis' options at each of the N synapse events.

There is a lot of parallel processing and redundancy in brain dynamics and many of these possible contributions may correspond to exactly the same possible experience 'e'. But in real life situations where there could be several different reasonable actions one cannot expect that every one of the 2^N alternative possible brain states will be a neural correlate of *exactly* the same possible 'e'. If the agent is conscious then the von Neumann Processes **1** and **3** must enter and determine which of the various alternative possible experiences 'e' actually occurs.

The analysis just given assumes, in accordance with the model of Fogelson and Zucker (Fogelson 1985), that the condition that triggers exocytosis is the presence of a specified number of calcium ions on a trigger site. Beck (2003) considers another possibility. He says that the "low exocytosis probability per excitatory impulse …means that there is an activation barrier against opening an ion channel in the PVG (presynaptic vesicular grid.) He proposes that "An incoming nerve pulse excites some electronic configuration to a metastable level, separated energetically by a potential barrier V(q) from the state that leads to the unidirectional process of exocytosis.” Then the state in which the exocytosis does occur can be considered to be connected by a *quantum tunneling process* to the state where it has not occurred.

Beck’s tunneling mechanism would achieve the same result as the mechanism, described above, which is based simply on the spreading of the wave packet due to Heisenberg’s uncertainty principle. Both mechanisms lead to the result that the brain state S(t) will contain 2^N states, defined by ‘exocytosis’ or ‘no exocytosis’ options independently at each of the N synapses. So the Eccles-Beck model does not lead to any essential difference from the vN/S model as regards this key point.

However, the Eccles-Beck proposal does differ importantly from the vN/S proposal in regard to their third point. The vN/S theory attributes the efficacy of will to the assumed power of mental effort to increase the rate of Process **1** actions, whereas the Eccles-Beck proposal attributes the efficacy of will to the assumed power of mental effort to modify *the probabilities associated with the Process **3** action*, the collapse of the quantum state.

The vN/S proposal stays rigorously within the framework of relativistic quantum field theory, and produces no causal anomalies, such as the possibility of sending messages backward in time, whereas the Eccles-Beck proposal, by disturbing the basic quantum probability rules, would in principle enable such anomalies to occur.

It is often correctly emphasized, in connection with quantum approaches to brain dynamics, that “the environment” will be affected differently by interactions with the brain states in which an exocytosis has or has not occurred, and that this difference will destroy, almost immediately, all (practically achievable) interference effects between these macroscopically distinct states.

This *environmental decoherence effect* is automatically included in the formulas used here, which refer explicitly to the brain state S(t), which is the brain-state statistical operator obtained by averaging (tracing) over all non-brain variables.

It is then sometimes concluded, incorrectly, that one can immediately replace the brain state S(t) by just *one* of these 2^N components. That conclusion might follow only if one were to ignore Process **1**, which is part of the brain process that defines which of our alternative possible thoughts actually occurs next. Since Process **1** is part of the process that determines which thought occurs next, it should depend upon the state S(t) of the brain *before* the thought occurs. The operator P(t), defined in the section 4, singles out the experience 'e' such that P(e) has maximal statistical weight *before the event*. It is defined by using the S(t) just prior to the collapse event, even though that instant will usually be after the environmental decoherence effect has occurred.

The model of the brain used above, with its 2^N well defined distinct components is, of course, highly idealized. A more realistic model would exhibit the general smearing out of all properties that follows from the quantum smearing out of the positions and velocities of all the particles. Thus the state S(t) prior to the collapse cannot realistically be expected ever to be rigorously divided, solely by Process **2** action, including interaction with the environment, into strictly orthogonal non-interfering components corresponding to distinct experiences. It is Process **1** that makes this crucial separation, not Process **2**. The recognition of the need to bring in a separate process, Process **1**, to achieve this end was one of von Neumann's key achievements, and any attempt to evade the need to include Process **1** faces daunting challenges.

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