ELECTROMAGNETIC MIND

Contents

Chapter 1

Electromagnetic theories of consciousness

The **electromagnetic theories of consciousness** propose that consciousness can be understood as an electromagnetic phenomenon.

1.1 Overview

Theorists differ in how they relate consciousness to electromagnetism. Electromagnetic *field* theories (or "EM field theories") of consciousness propose that consciousness results when a brain produces an electromagnetic field with specific characteristics. Susan Pockett[1] and Johnjoe McFadden[2][3][4] have proposed EM field theories; William Uttal[5] has criticized McFadden's and other field theories.

Some electromagnetic theories are also quantum mind theories of consciousness; examples include quantum brain dynamics (QBD) approaches of Mari Jibu and Kunio Yasue[6] and of Giuseppe Vitiello.[7] In general, however, quantum mind theories other than these QBD approaches do not treat consciousness as an electromagnetic phenomenon.

Also related are E. Roy John's work and Andrew and Alexander Fingelkurt's theory "Operational Architectonics framework of brain-mind functioning".[8]

1.2 Cemi theory

The starting point for McFadden and Pockett's theory is the fact that every time a neuron fires to generate an action potential, and a postsynaptic potential in the next neuron down the line, it also generates a disturbance in the surrounding electromagnetic field. McFadden has proposed that the brain's electromagnetic field creates a representation of the information in the neurons. Studies undertaken towards the end of the 20th century are argued to have shown that conscious experience correlates not with the number of neurons firing, but with the synchrony of that firing.[9] McFadden views the brain's electromagnetic field as arising from the induced EM field of neurons. The synchronous firing of neurons is, in this theory, argued to amplify the influence of the brain's EM field fluctuations to a much greater extent than would be possible with the unsynchronized firing of neurons.

McFadden thinks that the EM field could influence the brain in a number of ways. Redistribution of ions could modulate neuronal activity, given that voltage-gated ion channels are a key element in the progress of axon spikes. Neuronal firing is argued to be sensitive to the variation of as little as one millivolt across the cell membrane, or the involvement of a single extra ion channel. Transcranial magnetic stimulation is similarly argued to have demonstrated that weak EM fields can influence brain activity.

McFadden proposes that the digital information from neurons is integrated to form a conscious electromagnetic information (cemi) field in the brain. Consciousness is suggested to be the component of this field that is transmitted back to neurons, and communicates its state externally. Thoughts are viewed as electromagnetic representations of neuronal information, and the experience of free will in our choice of actions is argued to be our subjective experience of the cemi field acting on our neurons.

McFadden's view of free will is deterministic. Neurons generate patterns in the EM field, which in turn modulate the firing of particular neurons. There is only conscious agency in the sense that the field or its download to neurons is conscious, but the processes of the brain themselves are driven by deterministic electromagnetic interactions. The feel of subjective experience or qualia corresponds to a particular configuration of the cemi field. This field representation is in this theory argued to integrate parts into a whole that has meaning, so a face is not seen as a random collection of features, but as somebody's face. The integration of information in the field is also suggested to resolve the binding/combination problem.

In 2013, McFadden published two updates to the theory. In the first, 'The CEMI Field Theory: Closing the Loop' [10] McFadden cites recent experiments in the laboratories of Christof Koch[11] and David McCormick[12] which demonstrate that external EM fields, that simulate the brain's endogenous EM fields, influence neuronal firing patterns within brain slices. The findings are consistent with a prediction of the cemi field theory that the brain's endogenous EM field - consciousness - influences brain function. In the second, 'The CEMI Field Theory Gestalt Information and the Meaning of Meaning',[13] McFadden claims that that the cemi field theory provides a solution to the binding problem of how complex information is unified within ideas to provide meaning: the brain's EM field unifies the information encoded in millions of disparate neurons.

Susan Pockett[1] has advanced a theory, which has a similar physical basis to McFadden's, with consciousness seen as identical to certain spatiotemporal patterns of the EM field. However, whereas McFadden argues that his deterministic interpretation of the EM field is not out-of-line with mainstream thinking, Pockett suggests that the EM field comprises a universal consciousness that experiences the sensations, perceptions, thoughts and emotions of every conscious being in the universe. However, while McFadden thinks that the field is causal for actions, albeit deterministically, Pockett does not see the field as causal for our actions.

1.3 Quantum brain dynamics

Main article: Quantum brain dynamics

The concepts underlying this theory derive from the physicists, Hiroomi Umezawa[14] and Herbert Fröhlich[15] in the 1960s. More recently, their ideas have been elaborated by Mari Jibu and Kunio Yasue. Water comprises 70% of the brain, and quantum brain dynamics (QBD) proposes that the electric dipoles of the water molecules constitute a quantum field, referred to as the cortical field, with corticons as the quanta of the field. This cortical field is postulated to interact with quantum coherent waves generated by the biomolecules in neurons, which are suggested to propagate along the neuronal network. The idea of quantum coherent waves in the neuronal network derives from Frohlich. He viewed these waves as a means by which order could be maintained in living systems, and argued that the neuronal network could support long-range correlation of dipoles. This theory suggests that the cortical field not only interacts with the neuronal network, but also to a good extent controls it.

The proponents of QBD differ somewhat as to the way in which consciousness arises in this system. Jibu and Yasue suggest that the interaction between the energy quanta (corticons) of the quantum field and the biomolecular waves of the neuronal network produces consciousness. However, another theorist, Giuseppe Vitiello, proposes that the quantum states produce two poles, a subjective representation of the external world and also the internal self.

1.4 Objections

In a circa-2002 publication of The Journal of Consciousness Studies, the electromagnetic theory of consciousness faced an uphill battle for acceptance among cognitive scientists. Scientific study of consciousness has only recently begun to gain acceptance as a legitimate scientific discipline, and some think field theories like McFadden's are unscientific beliefs that threaten their hard-won legitimacy.

"No serious researcher I know believes in an electromagnetic theory of consciousness,"[16] Bernard Baars wrote in an e-mail. Baars is a neurobiologist and co-editor of Consciousness & Cognition, another scientific journal in the field. "It's not really worth talking about scientifically,"[16] he was quoted as saying.

McFadden acknowledges that his theory—which he calls the "cemi field theory"—is far from proven but he argues that it is certainly a legitimate line of scientific inquiry. His article underwent peer review before publication. In fact, Baars is on the editorial board of the journal that published it.

The field theories of consciousness do not appear to have been as widely discussed as other quantum consciousness theories, such as those of Penrose, Stapp or Bohm.[17][18][19] However, David Chalmers[20] argues that quantum theories of consciousness suffer from the same weakness as more conventional theories. Just as he argues that there is no particular reason why particular macroscopic physical features in the brain should give rise to consciousness, he also thinks that there is no particular reason why a particular quantum feature, such as the EM field in the brain, should give rise to consciousness either. Despite the existence of transcranial magnetic stimulation with medical purposes, Y. H. Sohn, A. Kaelin-Lang and M. Hallett have denied it,[21] and later Jeffrey Gray states in his book *Consciousness: Creeping up on the Hard Problem*, that tests looking for the influence of electromagnetic fields on brain function have been universally negative in their result .[22] However, a number of studies have found clear neural effects from EM stimulation.

- Dobson, (et al.) 2000 1.8 millitesla = 18,000 mG Interictal epileptiform activity enhanced and supressed in temporal lobe epileptics.
- Thomas (et al.), 2007 400 microtesla = 4000 milligauss Pain reduction in patients with fibromyalgia.
- Huesser, K. (et al.) .1 millitesla = 1000 mG Caused changes in EEG parameters.
- Marino (et al.), 2004 1 Gauss = 1000 mG Changes in EEG during presentation of Magnetic fields.
- Carrubba (et al.), 2008 1 Gauss = 1000 mG Evoked potentials detected.

- Bell (et al.) 2007 .78 Gauss = 780 mG Field_induced alterations in EEG
- Jacobson, 1994 5 picotesla = 0.00005 mG Direct correlation of melatonin production with magnetic field stimulation.
- Sandyk, R, 1999 “Picotesla range” (example:) 500 picotesla = 0.005 milligauss Magnetic fields improve olfactory function in Parkinson’s disease.

1.5 Advantages

Locating consciousness in the brain’s EM field, rather than the neurons, has the advantage of neatly accounting for how information located in millions of neurons scattered through the brain can be unified into a single conscious experience (sometimes called the binding or combination problem): the information is unified in the EM field . In this way EM field consciousness can be considered to be “joined-up information”. This theory accounts for several otherwise puzzling facts, such as the finding that attention and awareness tend to be correlated with the synchronous firing of multiple neurons rather than the firing of individual neurons. When neurons fire together their EM fields generate stronger EM field disturbances; so synchronous neuron firing will tend to have a larger impact on the brain’s EM field (and thereby consciousness) than the firing of individual neurons. However their generation by synchronous firing is not the only important characteristic of conscious electromagnetic fields—in Pockett’s original theory, spatial pattern is the defining feature of a conscious (as opposed to a non-conscious) field.

1.6 Influence on brain function

The different EM field theories disagree as to the role of the proposed conscious EM field on brain function. In McFadden’s cemi field theory, as well as in Drs Fingelkurts’ Brain-Mind Operational Architectonics theory, the brain’s global EM field modifies the electric charges across neural membranes, and thereby influences the probability that particular neurons will fire, providing a feed-back loop that drives free will. However, in the theories of Susan Pockett and E. Roy John, there is no necessary causal link between the conscious EM field and our consciously willed actions.

References to “Mag Lag” also known as the subtle effect on cognitive processes of MRI machine operators who sometimes have to go into the scanner room to check the patients and deal with issues that occur during the scan could suggest a link between magnetic fields and consciousness. Memory loss and delays in information processing have been reported, in some cases several hours after exposure. [23]

One hypothesis is that magnetic fields in the 0.5-9 Tesla range can affect the ion permeability of neural membranes, in fact this could account for a lot of the issues seen as this would affect many different brain functions.

1.7 Implications for artificial intelligence

If true, the theory has major implications for efforts to design consciousness into artificial intelligence machines;[24] current microprocessor technology is designed to transmit information linearly along electrical channels, and more general electromagnetic effects are seen as a nuisance and damped out; if this theory is right, however, this is directly counterproductive to creating an artificially conscious computer, which on some versions of the theory would instead have electromagnetic fields that synchronized its outputs—or in the original version of the theory would have spatially patterned electromagnetic fields.

Recent advances such as the discovery of the row hammer effect in DRAM suggests that with the right software an artificial intelligence could be constructed to utilize this inherently random effect in an existing laptop computer of sufficient memory density which represents another promising avenue of research.

A paper to be released suggests that the modification could be made to work on any laptop containing a dual or quad core CPU with only a single temperature sensor and heat spreader as long as it has DDR3 and a vulnerable SPD chip, susceptible machines include the Samsung x520 and Sony Vaio PCG-61611M.

1.8 See also

- Orchestrated objective reduction
- Quantum mind
- Simulated reality

1.9 References

[1] Susan Pockett. *The Nature of Consciousness*. ISBN 0-595-12215-9.

[2] Johnjoe McFadden (2002). “The Conscious Electromagnetic Information (Cemi) Field Theory: The Hard Problem Made Easy?". *Journal of Consciousness Studies* **9** (8): 45–60.

[3] Johnjoe McFadden (2002). “Synchronous Firing and Its Influence on the Brain’s Electromagnetic Field: Evidence for an Electromagnetic Field Theory of Consciousness”. *Journal of Consciousness Studies* **9** (4): 23–50.

[4] Johnjoe McFadden (2006). "12. The CEMI Field Theory: Seven Clues to the Nature of Consciousness". In Jack A. Tuszynski. *The Emerging Physics of Consciousness*. Berlin: Springer. pp. 385–404. ISBN 3-540-23890-5.

[5] William R. Uttal. *Neural Theories of Mind: Why the Mind-Brain Problem May Never Be Solved*. ISBN 0-8058-5484-3.

[6] Mari Jibu and Kunio Yasue. *Quantum brain dynamics and consciousness*. ISBN 1-55619-183-9.

[7] Giuseppe Vitiello. *My Double Unveiled*. ISBN 1-58811-076-1.

[8] Sources for Fingelkurts:

- Andrew A. Fingelkurts and Alexander A. Fingelkurts, Mapping of the Brain Operational Architectonics, published in: Chen, F. J. (ed.) Focus on Brain Mapping Research, Nova Science Publishers, 2005 pp. 59-98
- Fingelkurts A, Fingelkurst A (2001). "Operational architectonics of the human brain biopotential field: Towards solving the mind-brain problem" (PDF). *Brain and Mind* **2** (3): 261–296. doi:10.1023/a:1014427822738.
- Fingelkurts Andrew A., Fingelkurts Alexander A. (2004). "Making complexity simpler: Multivariability and metastability in the brain" (PDF). *International Journal of Neuroscience* **114** (7): 843–862. doi:10.1080/00207450490450046. PMID 15204050.
- Fingelkurts Andrew A., Fingelkurts Alexander A. (2006). "Timing in cognition and EEG brain dynamics: discreteness versus continuity" (PDF). *Cognitive Processing* **7** (3): 135–162. doi:10.1007/s10339-006-0035-0.
- Andrew A. Fingelkurts, Alexander A. Fingelkurts, Carlos F.H. Neves, Phenomenological architecture of a mind and Operational Architectonics of the brain: the unified metastable continuum. Journal of New Mathematics and Natural Computing, 2009, V. 5. No 1. P. 221-244

[9] Fries, P.; et al. (1997). "Synchronization of oscillatory responses in visual cortex correlates with perception in interocular rivalry". *PNAS* **94**: 2699–2704. Bibcode:1997PNAS...9412699F. doi:10.1073/pnas.94.23.12699. PMC 25091. PMID 9356513.

[10] McFadden, J. (2013). "The CEMI Field Theory Closing the Loop" (PDF). *Journal of Consciousness Studies* **20**: 153–168.

[11] Anastassiou,C.A.; et al. (2011). "Ephaptic coupling of cortical neurons". *Nature Neuroscience* **14** (2): 217–213. doi:10.1038/nn.2727. PMID 21240273.

[12] Frohlich,F.; McCormick,D.A. (2013). "Endogenous electric fields may guide neocortical network activity". *Neuron* **67**: 129–143. doi:10.1016/j.neuron.2010.06.005. PMC 3139922. PMID 20624597.

[13] McFadden, J. (2013). "The CEMI Field Theory Gestalt Information and the Meaning of Meaning" (PDF). *Journal of Consciousness Studies* **20**: 153–168.

[14] Hiroomi Umezawa. *Advanced Field Theory: Micro, Macro and Thermal Physics (1993)*. American Institute of Physics.

[15] Herbert Frohlich (1968). "Long-range coherence and energy storage in biological systems". *International Journal of Quantum Chemistry* **2**: 641–649. Bibcode:1968IJQC....2..641F. doi:10.1002/qua.560020505.

[16] "Consciousness Based on Wireless?". *Wired*. 21 May 2002.

[17] "Consciousness, biology and quantum hypotheses. [Phys Life Rev. 2012] - PubMed - NCBI". *Phys Life Rev* (Ncbi.nlm.nih.gov) **9**: 285–94. 2014-05-14. doi:10.1016/j.plrev.2012.07.001. PMID 22925839.

[18] "Near death experiences: a multidisciplinary hypothesis". Ncbi.nlm.nih.gov. 2013-09-11. Retrieved 2014-07-26.

[19] "Consciousness, the brain, and spacetime geometry". *Ann. N. Y. Acad. Sci.* **929**: 74–104. 2014-05-14. PMID 11349432.

[20] David Chalmers. *The Conscious Mind: In Search of a Fundamental Theory*. ISBN 0-19-510553-2.

[21] Sohn, Y H; Kaelin-Lang, A; Hallett, M (2003). "The effect of transcranial magnetic stimulation on movement selection". *Journal of Neurology, Neurosurgery & Psychiatry* **74** (7): 985–7. doi:10.1136/jnnp.74.7.985. PMC 1738563. PMID 12810802.

[22] Jeffrey Gray (2004). *Consciousness: Creeping up on the Hard Problem*. Oxford University Press. ISBN 0-19-852090-5.

[23] Occupational hazard? Working in MRI and the potential impact of EU PAD (EMF)

[24] Andrew A. Fingelkurts, Alexander A. Fingelkurts, Brain and mind Operational Architectonics and man-made "machine" consciousness. Cognitive Processing (2009) 10(2):105-111.

1.10 External links

- The electromagnetic field theory of consciousness, Scholarpedia
- Global workspace model of consciousness and its electromagnetic correlates
- Consciousness Based on Wireless?
- Quantum-Mind

Chapter 2

Quantum mind

Not to be confused with Quantum cognition.

The **quantum mind** or **quantum consciousness**[1] group of hypotheses propose that classical mechanics cannot explain consciousness. It posits that quantum mechanical phenomena, such as quantum entanglement and superposition, may play an important part in the brain's function and could form the basis of an explanation of consciousness. Tarlaci & Pregnolato (2015)[2] highlight the following distinct issues in quantum mind studies:

- The relationship of consciousness to the superposition-destroying observer in quantum mechanics
- Whether quantum physics has significance in biology
- Whether quantum physics has significance for the nervous system
- Whether psychiatric disorders can be explained by quantum physical changes

2.1 History

Eugene Wigner developed the idea that quantum mechanics has something to do with the workings of the mind . He proposed that the wave function collapses due to its interaction with consciousness. Freeman Dyson argued that "mind, as manifested by the capacity to make choices, is to some extent inherent in every electron."[3]

Other contemporary physicists and philosophers considered these arguments to be unconvincing.[4] Victor Stenger characterized quantum consciousness as a "myth" having "no scientific basis" that "should take its place along with gods, unicorns and dragons."[5]

David Chalmers argued against quantum consciousness. He instead discussed how quantum mechanics may relate to dualistic consciousness.[6] Chalmers is skeptical of the ability of any new physics to resolve the hard problem of consciousness.[7][8]

2.2 Quantum mind approaches

2.2.1 Bohm

David Bohm viewed quantum theory and relativity as contradictory, which implied a more fundamental level in the universe.[9] He claimed both quantum theory and relativity pointed towards this deeper theory, which he formulated as a quantum field theory. This more fundamental level was proposed to represent an undivided wholeness and an implicate order, from which arises the explicate order of the universe as we experience it.

Bohm's proposed implicate order applies both to matter and consciousness. He suggested that it could explain the relationship between them. He saw mind and matter as projections into our explicate order from the underlying implicate order. Bohm claimed that when we look at matter, we see nothing that helps us to understand consciousness.

Bohm discussed the experience of listening to music. He believed the feeling of movement and change that make up our experience of music derive from holding the immediate past and the present in the brain together. The musical notes from the past are transformations rather than memories. The notes that were implicate in the immediate past become explicate in the present. Bohm viewed this as consciousness emerging from the implicate order.

Bohm saw the movement, change or flow, and the coherence of experiences, such as listening to music, as a manifestation of the implicate order. He claimed to derive evidence for this from Jean Piaget's[10] work on infants. He held these studies to show that young children learn about time and space because they have a "hard-wired" understanding of movement as part of the implicate order. He compared this "hard-wiring" to Chomsky's theory that grammar is "hard-wired" into human brains.

Bohm never proposed a specific means by which his proposal could be falsified, nor a neural mechanism through which his "implicate order" could emerge in a way relevant to consciousness.[9] Bohm later collaborated on Karl Pribram's holonomic brain theory as a model of quantum consciousness.[11]

According to philosopher Paavo Pylkkänen, Bohm's suggestion "leads naturally to the assumption that the physical correlate of the logical thinking process is at the classically describable level of the brain, while the basic thinking process is at the quantum-theoretically describable level."[12]

2.2.2 Penrose and Hameroff

Main article: Orchestrated objective reduction

Theoretical physicist Roger Penrose and anaesthesiologist Stuart Hameroff collaborated to produce the theory known as Orchestrated Objective Reduction (Orch-OR). Penrose and Hameroff initially developed their ideas separately and later collaborated to produce Orch-OR in the early 1990s. The theory was reviewed and updated by the authors in late 2013.[13][14]

Penrose's argument stemmed from Gödel's incompleteness theorems. In Penrose's first book on consciousness, *The Emperor's New Mind* (1989), he argued that while a formal system cannot prove its own inconsistency, Gödel's unprovable results are provable by human mathematicians.[15] He took this disparity to mean that human mathematicians are not formal proof systems and are not running a computable algorithm. According to Bringsjorg and Xiao, this line of reasoning is based on fallacious equivocation on the meaning of computation.[16]

Penrose determined wave function collapse was the only possible physical basis for a non-computable process. Dissatisfied with its randomness, Penrose proposed a new form of wave function collapse that occurred in isolation and called it *objective reduction*. He suggested each quantum superposition has its own piece of spacetime curvature and that when these become separated by more than one Planck length they become unstable and collapse.[17] Penrose suggested that *objective reduction* represented neither randomness nor algorithmic processing but instead a non-computable influence in spacetime geometry from which mathematical understanding and, by later extension, consciousness derived.[17]

Hameroff provided a hypothesis that microtubules would be suitable hosts for quantum behavior.[18] Microtubules are composed of tubulin protein dimer subunits. The dimers each have hydrophobic pockets that are 8 nm apart and that may contain delocalized pi electrons. Tubulins have other smaller non-polar regions that contain pi electron-rich indole rings separated by only about 2 nm. Hameroff proposed that these electrons are close enough to become entangled.[19] Hameroff originally suggested the tubulin-subunit electrons would form a Bose–Einstein condensate, but this was discredited.[20] He then proposed a Frohlich condensate, a hypothetical coherent oscillation of dipolar molecules. However, this too was experimentally discredited.[21]

Furthermore, he proposed that condensates in one neuron could extend to many others via gap junctions between neurons, forming a macroscopic quantum feature across an extended area of the brain. When the wave function of this extended condensate collapsed, it was suggested to non-computationally access mathematical understanding and ultimately conscious experience that were hypothetically embedded in the geometry of spacetime.

However, Orch-OR made numerous false biological predictions, and is not an accepted model of brain physiology.[22] The proposed predominance of 'A' lattice microtubules, more suitable for information processing, was falsified by Kikkawa *et al.*,[23][24] who showed all in vivo microtubules have a 'B' lattice and a seam. The proposed existence of gap junctions between neurons and glial cells was also falsified.[25] Orch-OR predicted that microtubule coherence reaches the synapses via dendritic lamellar bodies (DLBs), however De Zeeuw *et al.* proved this impossible,[26] by showing that DLBs are located micrometers away from gap junctions.[27]

In January 2014, Hameroff and Penrose claimed that the discovery of quantum vibrations in microtubules by Anirban Bandyopadhyay of the National Institute for Materials Science in Japan in March 2013[28] corroborates the Orch-OR theory.[14][29]

In early 2015 it was revealed that pulsed transcranial ultrasound seems to improve memory functioning in Alzheimer's mice as well as helping to break down amyloid plaques.[30] This could be relevant to Orch-OR. Ultrasound activated latent brain repair and cleanup mechanisms; if it was also helping to boost the disease-weakened cemi field within the neurons in a similar way to adding noise to a signal sometimes boosts it above the noise floor then a similar high frequency ultrasound transmitter tuned to the specific microtubule vibrations could work even in patients in a persistent vegetative state.

2.2.3 Umezawa, Vitiello, Freeman

Hiroomi Umezawa and collaborators proposed a quantum field theory of memory storage. Giuseppe Vitiello and Walter Freeman proposed a dialog model of the mind. This dialog takes place between the classical and the quantum parts of the brain.[31][32] Their quantum field theory models of brain dynamics are fundamentally different from the Penrose-Hameroff theory.

2.2.4 Pribram, Bohm, Kak

Karl Pribram's holonomic brain theory (quantum holography) invoked quantum mechanics to explain higher order processing by the mind.[33][34] He argued that his holonomic model solved the binding problem.[35] Pribram collaborated with Bohm in his work on the quantum approaches to mind and he provided evidence on how much of the processing in the brain was done in wholes.[36] He proposed that ordered water at dendritic membrane surfaces might operate by structuring Bose-Einstein condensation supporting quantum dynamics.[37]

Although Subhash Kak's work is not directly related to that of Pribram, he likewise proposed that the physical substrate to neural networks has a quantum basis,[38][39] but asserted that the quantum mind has machine-like limitations.[40] He points to a role for quantum theory in the distinction between machine intelligence and biological intelligence, but that in itself cannot explain all aspects of consciousness.[41][42]

2.2.5 Stapp

Henry Stapp proposed that quantum waves are reduced only when they interact with consciousness. He argues from the Orthodox Quantum Mechanics of John von Neumann that the quantum state collapses when the observer selects one among the alternative quantum possibilities as a basis for future action. The collapse, therefore, takes place in the expectation that the observer associated with the state. Stapp's work drew criticism from scientists such as David Bourget and Danko Georgiev.[43] Georgiev[44][45] criticized Stapp's model in two respects:

- Stapp's mind does not have its own wavefunction or density matrix, but nevertheless can act upon the brain using projection operators. Such usage is not compatible with standard quantum mechanics because one can attach any number of ghostly minds to any point in space that act upon physical quantum systems with any projection operators. Therefore, Stapp's model negates "the prevailing principles of physics".[44]
- Stapp's claim that quantum Zeno effect is robust against environmental decoherence directly contradicts a basic theorem in quantum information theory that acting with projection operators upon the density matrix of a quantum system can only increase the system's Von Neumann entropy.[44][45]

2.3 Criticism

The main argument against the quantum mind proposition is that quantum states in the brain would decohere before they reached a spatial or temporal scale at which they could be useful for neural processing. This argument was elaborated by Tegmark. His calculations allowed him to conclude that quantum systems in the brain decohere at sub-picosecond timescales generally assumed to be too short to control brain function.[46][47] However, the extent to which we can predict where and when quantum behavior will end is still unclear. It has been established that photosynthesis depends on quantum processes in order to efficiently convert sunlight into chemical energy.[48] In 2015 researchers discovered an anomaly in the properties of ice at very cold temperatures near 20 K, which they explain by the quantum tunneling of multiple protons simultaneously.[49] Many other macroscopic quantum phenomena have been discovered, see Macroscopic quantum phenomena.

2.4 See also

- Bohm interpretation of quantum mechanics
- Electromagnetic theories of consciousness
- Evolutionary neuroscience
- Hameroff-Penrose Orchestrated Objective Reduction
- Hard problem of consciousness
- Holonomic brain theory
- Mechanism (philosophy)
- Quantum cognition
- Theory of mind

2.5 References

[1] "Quantum Approaches to Consciousness". Stanford Encyclopedia of Philosophy. May 19, 2011 [First published Tue Nov 30, 2004].

[2] Tarlacı, Sultan; Pregnolato, Massimo (2015). "Quantum neurophysics: From non-living matter to quantum neurobiology and psychopathology.". *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*. doi:10.1016/j.ijpsycho.2015.02.016. PMID 25668717.

[3] Dyson, Freeman (2004). *Infinite in All Directions: Gifford Lectures Given at Aberdeen, Scotland April--November 1985* (1st Perennial ed.). New York: Perennial. p. 297. ISBN 0060728892.

[4] Searle, John R. (1997). *The Mystery of Consciousness* (1. ed.). New York: New York Review of Books. pp. 53–88. ISBN 9780940322066.

[5] Stenger, Victor. *The Myth of Quantum Consciousness* (PDF). *The Humanist*. 53 No 3 (May–June 1992). pp. 13–15.

[6] Stephen P. Stich; Ted A. Warfield (15 April 2008). *The Blackwell Guide to Philosophy of Mind*. *Blackwell Philosophy Guides* (John Wiley & Sons). p. 126. ISBN 9780470998755.

[7] David J. Chalmers (1995). "Facing Up to the Problem of Consciousness". *Journal of Consciousness Studies* **2** (3): 200–219.

[8] Chalmers, David J. (1997). *The Conscious Mind: In Search of a Fundamental Theory* (Paperback ed.). New York: Oxford University Press. ISBN 978-0-19-511789-9.

[9] Bohm, David (2002). *Wholeness and the Implicate Order*. (Online-Ausg. ed.). Hoboken: Routledge. ISBN 0203995155.

[10] Piaget, Jean (1997). *Jean Piaget: selected works. (The Origin of Intelligence in the Child)* (Repr. ed.). London: Routledge. ISBN 9780415168861.

[11] Wade, Jenny (1996). *Changes of Mind: A Holonomic Theory of the Evolution of Consciousness*. Albany: State Univ. of New York Press. ISBN 9780791428498.

[12] Paavo Pylkkänen. "Can quantum analogies help us to understand the process of thought?" (PDF). *Mind & Matter* **12** (1): 61–91. p. 75.

[13] unattributed (2014-01-16). "Discovery of Quantum Vibrations in...". sciencedaily.com. Retrieved 2014-01-16.

[14] "Discovery of Quantum Vibrations in "Microtubules" Inside Brain Neurons Corroborates Controversial 20-Year-Old Theory of Consciousness". Elsevier. Retrieved 2014-08-04.

[15] Gödel, Kurt (1992). *On Formally Undecidable Propositions of Principia Mathematica and Related Systems* (Reprint. ed.). New York: Dover Publications. ISBN 0486669807.

[16] Bringsjord, S. and Xiao, H. 2000. *A Refutation of Penrose's Gödelian Case Against Artificial Intelligence.* Journal of Experimental and Theoretical Artificial Intelligence

[17] Penrose, Roger (1999). *The Emperor's New Mind: Concerning Computers, Minds, and the Laws of Physics* ([New edition] ed.). Oxford: Oxford Univ. Press. ISBN 0192861980.

[18] Penrose, Roger (1995). *Shadows of the Mind: A Search for the Missing Science of Consciousness* (Repr. (with corrections). ed.). Oxford [u.a.]: Oxford Univ. Press. ISBN 0198539789.

[19] Hameroff, Stuart (2008). "That's life! The geometry of π electron resonance clouds". In Abbott, D; Davies, P; Pati, A. *Quantum aspects of life* (PDF). World Scientific. pp. 403–434. Retrieved Jan 21, 2010.

[20] Roger Penrose & Stuart Hameroff (2011). "Consciousness in the Universe: Neuroscience, Quantum Space-Time Geometry and Orch OR Theory". *Journal of Cosmology* **14**.

[21] Reimers, Jeffrey R.; McKemmish, Laura K.; McKenzie, Ross H.; Mark, Alan E.; Hush, Noel S. (17 March 2009). "Weak, strong, and coherent regimes of Fröhlich condensation and their applications to terahertz medicine and quantum consciousness". *PNAS* **106** (11): 4219–4224. Bibcode:2009PNAS..106.4219R. doi:10.1073/pnas.0806273106. PMC 2657444. PMID 19251667. Retrieved 10 June 2013.

[22] Khoshbin-e-Khoshnazar M.R. (2007). "Achilles' Heels of the 'Orch OR' Model".*NeuroQuantology* **5(1)**:182-185. doi: 10.14704/nq.2007.5.1.123

[23] Kikkawa, M., Ishikawa, T., Nakata, T., Wakabayashi, T., Hirokawa, N. (1994). "Direct visualization of the microtubule lattice seam both in vitro and in vivo". *Journal of Cell Biology* **127** (6): 1965–1971. doi:10.1083/jcb.127.6.1965. PMC 2120284. PMID 7806574.

[24] Kikkawa, M., Metlagel, Z. (2006). "A molecular "zipper" for microtubules". *Cell* **127** (7): 1302–1304. doi:10.1016/j.cell.2006.12.009. PMID 17190594.

[25] F. J. Binmöller & C. M. Müller (1992). "Postnatal development of dye-coupling among astrocytes in rat visual cortex". *Glia* **6** (2): 127–137. doi:10.1002/glia.440060207. PMID 1328051.

[26] De Zeeuw, C.I., Hertzberg, E.L., Mugnaini, E. (1995). "The dendritic lamellar body: A new neuronal organelle putatively associated with dendrodentritic gap junctions". *Journal of Neuroscience* **15** (2): 1587–1604. PMID 7869120.

[27] "Consciousness, the brain, and spacetime geometry". 2013-08-12. Retrieved 2014-01-16.

[28] "Atomic water channel controlling remarka... [Biosens Bioelectron. 2013] - PubMed - NCBI". Ncbi.nlm.nih.gov. 2014-05-14. Retrieved 2014-07-30.

[29] Osborne, Hannah (2014-01-16). "Quantum Vibrations in Brain Opens 'Pandora's Box' of Theories of Consciousness - Yahoo News UK". Uk.news.yahoo.com. Retrieved 2014-08-04.

[30] "Ultrasound 'breakthrough' in treating Alzheimer's - in mice - Health News - NHS Choices". Nhs.uk. 2015-03-12. Retrieved 2015-03-31.

[31] G. Vitiello, My Double Unveiled. John Benjamins, 2001.

[32] Freeman, W. and G. Vitiello, Nonlinear brain dynamics as macroscopic manifestation of underlying many-body dynamics. Physics of Life Reviews, vol. 3, pp 93-118, 2006.

[33] Pribram, K. H. (1999). Quantum holography: Is it relevant to brain function? Information Sciences, 115(1–4), 97–102.

[34] Pribram, K.H. (2004). Consciousness Reassessed. Mind and Matter, 2, 7–35.

[35] Pribram, K. (1999) Status Report: Quantum Holography and the Braln. Acta Polyiechnica Scandinavica: Emergence Complexity, Hierarchy, Organization, Vol. 2, pp. 33-60.

[36] Pribram, K.H. Holography, holonomy and brain function. Elsevier's Encyclopedia of Neuroscience, 1999.

[37] Jibu, M., Pribrm, K. H., & Yasue, K. (1996). From conscious experience to memory storage and retrieval: The role of quantum brain dynamics and boson condensation of evanescent photons. International Journal of Modern Physics B, 10, 1735-1754.

[38] Kak, S. (1995) Quantum neural computing, In Advances in Imaging and Electron Physics, vol. 94, P. Hawkes (editor). Academic Press, 259-313.

[39] Kak, S. (1996) The three languages of the brain: quantum, reorganizational, and associative. In Learning as Self- Organization, K. Pribram and J. King (editors). Lawrence Erlbaum Associates, Mahwah, NJ, 185-219.

[40] Gautam, A. and S. Kak (2013), Symbols, meaning, and origins of mind. Biosemiotics (Springer Verlag) 6: 301-310.

[41] Kak, S. (2000), Active agents, intelligence, and quantum computing. Information Sciences 128: 1-17.

[42] Kak, S. (2005), Artificial and biological intelligence. ACM Ubiquity 6 (42): 1-22.

[43] Bourget, D. (2004). "Quantum Leaps in Philosophy of Mind: A Critique of Stapp's Theory". *Journal of Consciousness Studies* **11** (12): 17–42.

[44] Georgiev, D. (2012). "Mind efforts, quantum Zeno effect and environmental decoherence". *NeuroQuantology* **10** (3): 374–388. doi:10.14704/nq.2012.10.3.552.

[45] Georgiev, D. (2015). "Monte Carlo simulation of quantum Zeno effect in the brain". *International Journal of Modern Physics B* **29** (7): 1550039. arXiv:1412.4741. doi:10.1142/S0217979215500393.

[46] Tegmark, M. (2000). "Importance of quantum decoherence in brain processes". *Physical Review E* **61** (4): 4194–4206. arXiv:quant-ph/9907009. Bibcode:2000PhRvE..61.4194T. doi:10.1103/PhysRevE.61.4194.

[47] Charles Seife (4 February 2000). "Cold Numbers Unmake the Quantum Mind". *Science* **287** (5454): 791. doi:10.1126/science.287.5454.791. PMID 10691548.

[48] Engel, G. (2007). "Evidence for wavelike energy transfer through quantum coherence in photosynthetic systems". *Nature* **446** (7137): 782–786. doi:10.1038/nature05678. PMID 17429397.

[49] Yen, F. and Gao, T. (2015). "Dielectric Anomaly in Ice near 20 K: Evidence of Macroscopic Quantum Phenomena". *Journal of Physical Chemistry Letters* (July). doi:10.1021/acs.jpclett.5b00797.

2.6 Further reading

- Flanagan, Brian. *Are Perceptual Fields Quantum Fields?*
- Hodgson, David (1993). *The Mind Matters: Consciousness and Choice in a Quantum World*. Clarendon Press. ISBN 978-0-19-824068-6.
- Koch, C. and Hepp, K., "Quantum mechanics in the brain", *Nature* 440, 611 (30 March 2006)
- Litt et al., "Is the Brain a Quantum Computer?", *Cognitive Science* (2006)
- Lockwood, Michael (1995). *Mind, Brain, and the Quantum: The Compound 'I'*. Basil Blackwell.
- McFadden, Johnjoe (2000) *Quantum Evolution* HarperCollins. ISBN 0-00-255948-X; ISBN 0-00-655128-9 . Final chapter on the quantum mind.
- Pharaoh, M.C. (online). Looking to quantum mechanics for a reductive explanation of the noumenon of consciousness Retrieved June.21 2008.
- Schrödinger, Erwin (January 2003). *Mind and Matter*. Textbook Publishers. ISBN 978-0-7581-1275-0.
- Weyl, Hermann Claus Hugo (1934). *Mind and Nature*. University of Pennsylvania Press.
- Wigner, Eugene (1981). "Physics and the Explanation of Life". In Lindsay, Robert Bruce. *Foundations of Physics* **1**. Ox Bow Press. pp. 34–35. ISBN 978-0-918024-17-6. |first2= missing |last2= in Editors list (help)
- Khoshbin-e-Khoshnazar, M.R. (January 2016). Possible Application of Variational Cluster Expansion in Modeling Correlated Neurons. Journal of Consciousness Exploration & Research Vol.7(1), pp.122-125.

2.7 External links

- Center for Consciousness Studies, directed by Stuart Hameroff
- Online papers on consciousness
- Stanford Univ. Encyclopedia of Philosophy critical survey article Harald Altmanspacher (2006) *Quantum Approaches to Consciousness*
- "What is an Essentially Quantum Mechanical Effect?", Osvaldo Pessoa Jr.
- Quantum-Mind

2.8 Text and image sources, contributors, and licenses

2.8.1 Text

- **Electromagnetic theories of consciousness** *Source:* https://en.wikipedia.org/wiki/Electromagnetic_theories_of_consciousness?oldid=713603790 *Contributors:* Slusk, BenRG, Centrx, Pascal666, Alexf, LucasVB, Icairns, Deglr6328, Dbachmann, Enric Naval, I9Q79oL78KiL0QTFHgyc, Calton, DV8 2XL, Loxley~enwiki, Dmitry Brant, WadeSimMiser, Mpatel, Sparkit, Theboywonder, Rjwilmsi, Phatmonkey, Deskana, Długosz, Equilibrial, Pnrj, SamuelRiv, Sandstein, 2over0, Lserni, SmackBot, Bluebot, Liontooth, Clicketyclack, AmeriCan, CmdrObot, Glen Davidson, Headbomb, Magioladitis, ***Ria777, Cgingold, WLU, Persephone19, Sanitycult, Tarotcards, Fences and windows, DUBJAY04, J4m3sb0nd, Myscience, Lova Falk, Wing gundam, EPadmirateur, ClueBot, Auntof6, Johnjoemcfadden, Dsimic, Addbot, Uruk2008, Looie496, Yobot, Evans1982, AnomieBOT, Shevchenko Nikolay, Citation bot, Obersachsebot, Red Hong, Omnipaedista, Aaron Kauppi, Jaythreeo0, FrescoBot, Paine Ellsworth, Citation bot 1, Gil987, Three887, Tom.Reding, Skyerise, RjwilmsiBot, Scgtrp, Sudozero, HRO'Neill, Helpful Pixie Bot, Bibcode Bot, LizzardKitty, EMIConscious, MrBill3, BattyBot, ChrisGualtieri, Fixuture, EChastain, Jerodlycett and Anonymous: 54
- **Quantum mind** *Source:* https://en.wikipedia.org/wiki/Quantum_mind?oldid=713641565 *Contributors:* The Anome, Roadrunner, Stevertigo, Michael Hardy, Tim Starling, Dcljr, Docu, William M. Connolley, JWSchmidt, Ciphergoth, Geoff, Maximus Rex, Joy, BenRG, Lumos3, David Gerard, Mporter, Barbara Shack, Remy B, Eequor, Just Another Dan, Mporch, Gadfium, Lincolndogs, Danko Georgiev, Sharavanabhava, Gary D, Salimfadhley, Rculatta, Chris Howard, Patrickwilken, Brianhe, Rich Farmbrough, Antaeus Feldspar, Dbachmann, ESkog, PhilHibbs, Touriste, Enric Naval, Giraffedata, Famousdog, Pearle, Matpitka, Titanium~enwiki, Jared81, Keenan Pepper, CLAVDIVS, Bruce Couper, Ombudsman, Terrible tony, Memenen, Oleg Alexandrov, Loxley~enwiki, Dmitry Brant, Bobrayner, Shoyer, Mandarax, Sparkit, Rjwilmsi, Thangalin, Fragglet, Jfraatz, Sperxios, Arjuna909, Długosz, Cholmes75, Ospalh, SamuelRiv, 2over0, Pietdesomere, Lserni, SmackBot, Mitteldorf, InverseHypercube, DCDuring, WildElf, ParlorGames, Delta Tango, Colonies Chris, Liontooth, Huon, Radagast83, Nihilo 01, Pwjb, BullRangifer, Occultations, Ckatz, Ripe, Hypnosifl, Dr.K., Kvng, Michaelbusch, Joseph Solis in Australia, CapitalR, Jlugert, RookZERO, CmdrObot, JohnCD, Jhskulk, Gregbard, Cydebot, Peterdjones, Headbomb, Second Quantization, Stephen Patrick, WikiSlasher, Dbrodbeck, And4e, Lkitrossky, LuckyLouie, Lfstevens, Salad Days, Jahn Henne, Dilane, WhatamIdoing, JaGa, WLU, TimidGuy, B9 hummingbird hovering, Alsee, Peterwshor, R'n'B, Persephone19, The Anonymous One, Maurice Carbonaro, Dndn1011, George963 au, Shawn in Montreal, Davy p, Warut, Bjflanagan, STBotD, Winnow, Littleolive oil, VolkovBot, Julia Neumann, JohnBlackburne, WOSlinker, Inflector, Ask123, Jbusemey, Lucywills, Lamro, Stevo46, Moonriddengirl, Malcolmxl5, Mark Germine, M.D., RJaguar3, Wing gundam, Likebox, Allmightyduck, SearedAji, Agalmic, DFRussia, Niceguyedc, Arne Heise, Jumbolino, Yoman82, XLinkBot, Sietec, Gumum, Dthomsen8, Masegi, Mark Pharoah, Addbot, Uruk2008, Fladrif, Looie496, Proxima Centauri, QuackOfaThousandSuns, Cesaar, Fryed-peach, Yobot, Ptbotgourou, Edoe, AnomieBOT, Jeoffry.smart, Citation bot, Capricorn42, Michael Lazaro, DSisyphBot, Ched, Johnxe22, Xasodfuih, Astatine-210, Aaron Kauppi, NoldorinElf, FrescoBot, Sławomir Biały, Lightbound, Machine Elf 1735, Zimmy 1970, Citation bot 1, Sopher99, Gil987, Abductive, Three887, Skyerise, Casimir9999, Hickorybark, Lotje, Cutelyaware, Decoh3371, EleferenBot, Fæ, Naviguessor, AndyTheGrump, Swabaxter, HRO'Neill, Metathink, Frietjes, Braincricket, Dream of Nyx, Helpful Pixie Bot, Bibcode Bot, Jeraphine Gryphon, BG19bot, Gautehuus, FiveColourMap, Sigilian, Davidcpearce, BattyBot, Jimw338, ReverseTelescope, Josophie, Polambda, Andyhowlett, BriseisGatto, KirstenRichards, Carogutt, Arlene47, Brianjflanagan, 2PeterElls, Monkbot, Gronk Oz, Thundergodz, Decoh3391, Aerosheet, Jimmywagtail01, LikiMike, Weegeerunner, Rhoark, Julius Paisley, NG7857, Neuroscience325, SocraticOath, Future Kick, Horror Dolls, Drtetractous and Anonymous: 190

2.8.2 Images

- **File:Question_book-new.svg** *Source:* https://upload.wikimedia.org/wikipedia/en/9/99/Question_book-new.svg *License:* Cc-by-sa-3.0 *Contributors:*

  Created from scratch in Adobe Illustrator. Based on Image:Question book.png created by User:Equazcion *Original artist:*

  Tkgd2007
- **File:Wiki_letter_w_cropped.svg** *Source:* https://upload.wikimedia.org/wikipedia/commons/1/1c/Wiki_letter_w_cropped.svg *License:* CC-BY-SA-3.0 *Contributors:* This file was derived from Wiki letter w.svg:
  Original artist: Derivative work by Thumperward

2.8.3 Content license