The Problems of Quantum Mechanics and Possible Solutions :

Copenhagen Interpretation, Many Worlds Interpretation, Transactional Interpretation, Decoherence and Quantum Logic

by Rochelle Forrester

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Abstract

This paper reviews some of the literature on the philosophy of quantum mechanics. The publications involved tend to follow similar patterns of first identifying the mysteries, puzzles or paradoxes of the quantum world, and then discussing the existing interpretations of these matters, before the authors produce their own interpretations, or side with one of the existing views. The paper will show that all interpretations of quantum mechanics involve elements of apparent weirdness. They suggest that the quantum world, and possibly our macro world, exists or behaves in a way quite contrary to the way we normally imagine they should. The paper will also show how many of the writers on quantum mechanics misunderstand idealism in the macro world as proposed by philosophers such as George Berkeley, David Hume, Immanuel Kant and John Stuart Mill and misunderstand the concept of the observer dependent universe. The paper concludes by examining the similarities between the idealist view of the macro

world and the Copenhagen Interpretation of the quantum world and suggests that as the Copenhagen Interpretation provides a view of the quantum world that is consistent with the macro world then the Copenhagen Interpretation should be the preferred view of the quantum world.

The Problems of Quantum Mechanics

Quantum mechanics describes to us the strange world of subatomic particles. The very names of some of the publications on quantum mechanics gives some idea of the extraordinary nature of quantum mechanics. *The Mystery of the Quantum World, Where does the weirdness go?, Particles and Paradoxes, The Ghost in the Atom, Quantum Physics: Illusion or Reality* gives some idea of the extraordinary nature of the quantum world. This strangeness relates to certain matters which emerge from various experiments performed using quantum entities and electromagnetic energy. There are a number of such experiments, but there are six main experiments. They are the double slit experiment, the EPR-Aspect experiment, the Stern-Gerlach experiments, polarization experiments, barrier experiments involving quantum tunneling and a thought experiment known as the Schrodinger's cat experiment. Different publications handle these experiments differently, some emphasizing one, some emphasizing others.

The simplest explanation of the experiments is given in *Where does the weirdness go?* in which all except the polarization and barrier experiments are considered. In that book David Lindley considers the results of these experiments are weird and bewildering rather than paradoxical in that they are not internally contradictory. What they contradict is our normal view of reality. However there is one genuine paradox in quantum mechanics. This concerns the question of how measurements can be made; how measurements turn indeterminate quantum systems into definite states and how measuring devices may exist in definite states, when the quantum systems they are made of, are in indefinite states unless observed. (Lindley, 1997, 163-165).

A more detailed statement of the difficulties the quantum world presents us with, is provided by Peter Gibbins in his book *Particles and Paradoxes.* That statement is as follows:

"Does quantum mechanics describe individual quantum systems or only the statistical behavior of ensembles of quantum systems?
Are quantum systems waves, or particles, both or neither?
How should we understand the uncertainty principle?
What does probability mean in quantum mechanics?
Do individual quantum systems have precise values for all their dynamical variables?
Do electrons have trajectories?
Can there be a deterministic hidden variables underpinning of quantum mechanics?
How are we to understand measurement in quantum mechanics?
Is quantum mechanics a non-local theory?
Are there genuine paradoxes in quantum mechanics, how can they be resolved?
Can they be resolved by restricting our reasoning about individual systems to quantum logic?

Is quantum logic a logic?" (Gibbins, 1987, 13-14)

The last three questions asked by Gibbins relate particularly to his book which specifically deals with quantum logic, a system of logic that varies somewhat from the classical logic familiar to philosophers. The replacement of classical logic with a special quantum logic may seem a desperate remedy for the peculiarities of the quantum world but all explanations as to what happens in the quantum world have an aura of desperation about them.

There are of course many other interpretations, of what constitutes the strangeness of the quantum world. Peter Forrest describes some of them in Chapter 3 of his book *Quantum Metaphysics* under the heading "Puzzles and Problems". The first puzzle he raises is that concerning Schrodinger's Cat which is a thought experiment concerning the relationship between quantum theory and macroscopic objects. The puzzle concerns a macroscopic object such as a cat which according to quantum theory as applied in the thought experiment is in a state of being neither dead nor alive. Such a state is of course contrary to the way we normally experience cats. Forrest's version of Schrodinger's cat uses plaster cats that are blown up by a terrorist organization but the puzzle remains as to how his plaster cats can be both blown up (e.g. dead) and not blown up (e.g. alive) at the same time.

Forrest then raises the problem of there being two quite different sorts of dynamics for quantum systems. Systems may behave in accordance with Schrodinger dynamics, or when an observation is made, in accordance with von Neumann dynamics. This, Forrest says, raises problems of incoherence, demarcation and complexity. Incoherence arises as measurements are meant to obey von Neumann dynamics and yet measurements are simply physical interactions of quantum systems and as such should obey Schrodinger dynamics. Demarcation is the problem of where to draw the line between the von Neumann dynamics and Schrodinger dynamics and complexity concerns having two dynamics for two different situations while our intuition is that there should be a single account of the physical world.

Forrest's third problem is that of veridicality. What should we regard as truth in quantum theory'? Should truth be based on a "realist" basis or some "idealist" or "phenomenalist" basis or on some statistical basis. Forrest's fourth problem concerns the double slit experiment and the problems revealed by that experiment. His fifth problem concerns whether or not it is possible for an electron to have a precise position and momentum at the same time, apart from measurement problems such as the uncertainty principle. The sixth problem concerns problems involving quantum systems that are in a mixture of states for example some having spin up and some having spin down. The seventh problem concerns action at a distance which Forrest considers in relation to both the double slit experiment and the EPR/Aspect experiment.

John Gribbin, in *Schrodinger's Kittens,* presents his understanding of the problems of quantum mechanics in the prologue to his book; under the heading "The problem". Gribbin mainly illustrates the problems by reference to the double slit experiment in which light is sent through a screen with two slits and produces a pattern of light and dark patches on a second screen which shows light as a wave. The light and dark patches are the result of interference between light waves some of which reinforce each other to produce the light patches and others cancel each other out to produce the dark patches. If adjustments are made to the experiments such as closing a slit or placing a detector at one of the slits, light can be shown to consist of particles known as photons. Photons are indivisible and are the smallest bits of light possible. One problem is why should light suddenly change from wave to particles when a detector is placed at one of the slits and why should opening and closing slits cause light to change from wave to particle and vice versa?

If light is sent through the experiment a single photon at a time, then again we see the pattern of light and dark patches considered to be caused by light waves interfering with each other. This leads to another of the problems raised by John Gribbin. How does the single indivisible photon go through both holes at once so as to produce the interference pattern on the second screen. A further problem is how does each individual photon know where to land on the second screen? Why doesn't each photon follow the path of the previous photon and end up on the same spot as the previous photon? Furthermore these effects are not limited to photons but apply to other quantum entities, such as electrons, protons and neutrons and atoms. The problem also arises that the results given by the double slit experiment do not show up in the macro world. If one threw balls through holes in a wall one would not observe balls piling up in a pattern similar to the way quantum entities hit the second screen in the double slit experiment. Does this mean there is some level at which the rules of the quantum world cease to apply and if so why are there two sets of rules, one for the quantum world and one for the macro world.

An additional problem raised by Gribbin is that of non-locality. This is shown in the double slit experiment when a quantum entity passes through one hole of the first screen behaves differently (eg like a wave if the other hole is open, like a particle if it is closed) depending on whether the other hole is open or closed. How does the quantum entity "know" whether the other hole is open or closed. Non locality is even more dramatically shown by another experiment known as the Aspect experiment. This experiment according to Alain Aspect, who lead the group performing the experiment and John Bell who developed Bell's Theorem a substantial part of the theory behind the Aspect experiment, shows that either the idea of non locality applies, which is contrary to the theory of special relativity as it involves faster than light signaling, or we drop the view of an external world that is independent of our observations and adopt an observer dependent world. (Davies & Brown (ed), 1986, 43 & 48). Obviously the problem here is that the theory of special relativity has tremendous experimental support so it should not be lightly dropped and the ideas of a world external to our senses is the common sense view of the world and so it should not be lightly dropped. But one of these needs to be discarded.

The last problem identified by Gribbin concerns the Schrodinger’s cat thought experiment, which illustrates the key role the observer plays in the quantum world and the relationship between the quantum and macro worlds. In the Schrodinger’s cat experiment a conscious observer is needed to bring everything in the experiment into existence. Without the observer everything remains suspended in limbo or in a superposition of states. The other point to emerge from the Schrodinger cat experiment is that the cat and the experiment do not exist until observed which is quite contrary to our normal common sense view of macro objects like cats.

A summary of the problems of quantum mechanics as seen by John Gribbin is wave/particle duality, for example why should quantum entities sometimes behave as particles and sometimes as waves, non locality, why is an observer necessary to make quantum entities real and why is there a difference between how things work in the quantum and macro worlds?

Euan Squires in *The Mystery of the Quantum World* is mainly concerned with questions such as do quantum mechanical effects take place when measured or do they exist independent of measurement?; how does measurement take place?; whether conscious observers are necessary for measurement; how does measurement occur and is the wave function real and does it reduce? Squires illustrates these problems by reference to various experiments, one of which is the potential barrier experiment. In this experiment a particle of a certain velocity is directed against a barrier. On some occasions the particle will pass through the barrier (i.e. it is transmitted) by a process unique to the quantum world, known as tunneling. On other occasions the particle will not penetrate the barrier and will be reflected from the barrier. In this quantum mechanical situation, there is no way in which we can predict whether an individual particle will be transmitted or reflected, but we can describe the behavior of a large number of such particles and assess the probability of any individual particle being transmitted or reflected.

Squires uses another version of this experiment (in this case a thought experiment) to illustrate interference and non locality. This experiment involves using mirrors to deflect both the transmitted and reflected particles via different paths towards a set of detectors. This experiment is also a version of the double slit experiment in that the two beams of particles interfere to produce the interference pattern of alternative light and dark patches on the detectors. Non locality is illustrated when one of the mirrors is removed so there is only a single beam of particles and the interference pattern disappears, suggesting that somehow the particles knew that one of the mirrors had been removed.

A fuller description of non locality is given by Squires when examining the EPR/Aspect experiment. This experiment began as a thought experiment proposed by Einstein, Podolsky and Rosen and became capable of being carried out in principle due to the work of John Bell who considerably refined and developed the experiment. Eventually the experiment was carried out in practice the most complete version of the experiment being carried out by Alain Aspect. The result of the EPR/Aspect experiments is usually considered to leave us with a choice of giving up locality and accepting faster than light signaling or giving up realism, the belief that things and their properties exist independent of observers.

Overall it is apparent that while the literature describes the puzzles quantum mechanics provides us in a variety of ways, there nevertheless is a degree of agreement as to what the puzzles are. There is however much disagreement as to how to interpret and understand the results of those experiments that provide us with our quantum mechanical puzzles.

The answers to the problems of Quantum Mechanics

What explanations are given for the behavior of quantum systems? The orthodox explanation is the Copenhagen interpretation. The Copenhagen interpretation has a number of different versions each providing a different emphasis on the varying aspects of the explanations of the puzzles produced by experiments such as the double slit experiment. The Copenhagen interpretation has a number of aspects such as the collapse of the wave function, the uncertainty principle and complementarity.

The collapse of the wave function is a process which occurs whenever an observation or measurement is made of a quantum entity. The wave function is not a real wave like waves in the ocean. Rather the wave function is an abstract mathematical concept representing, “a complex form of vibration in an imaginary mathematical space called configuration space.” (Gribbin, 1984, 116). The picture of physically real waves in quantum mechanics is wrong, (Gribbin, 1984, 117) the waves are simply mathematical concepts based on probability. The mathematics produced by the wave function can be provided in a non-wave manner by the quantum algebra produced by Paul Dirac and the matrix mechanics produced by Heisenberg, Born and Jordan. (Gribbin, 1984, 114). The wave function, based on work by Erwin Schrodinger and Max Born provides a measure of the probability of finding a particular particle at any given place. In the double slit experiment a given electron may be anywhere in the universe, but it is more likely to turn up in the dark patches of an interference pattern.

The uncertainty principle concerns the impossibility of obtaining precise measurements of certain pairs of properties of quantum entities. The example usually given is that of the position and momentum of an electron, the principle stating the more precisely we try to measure the position of an electron the less precisely we will be able to measure its momentum. The principle is sometimes explained on the basis that the only way we can observe an electron’s position is by bouncing photons off it, which will tell us the electron's position. However the collision between the photon and the electron will disturb the electron's momentum making it impossible to measure both position and momentum at the same time.

This however is not the full story. The mathematics of quantum theory make it clear that electrons and other quantum entities simply do not have a precise position and a precise momentum. It may have a precise position but then it will not have any knowable momentum at all, or it may have a precise momentum, but its position will not be knowable. (Gribbin, 1984, 157).

Complementarity is simply the idea that the quantum world can be seen in alternate ways. One can for example see it in terms of waves by performing the double slit experiment or in terms of particles by placing detectors at the slits. Both the wave view and the particle view are necessary to understand the quantum world. They can be seen as different sides of the same coin. Any experiment designed to show waves, will show waves, any experiment designed to show particles will show particles, however no experiment will be able to show both wave and particle pictures of the quantum world at the same time. It should be mentioned however that an experiment has been performed in Japan which shows the same photons acting as both wave and particle at the same time. (Gribbin, 1995, 119-120).

The consequences of the Copenhagen interpretation is that the observer plays a critical role in determining how the world is. The behavior of atoms, electrons and light depends on whether an observation is being made. If it is, then the wave function collapses and they behave as particles. If no observation is made, then electrons, atoms and light behave as waves as is shown by the phenomena of interference in the double slit experiment. The waves however are probability waves which do not have any material form; they are just mathematical concepts. Heinz Pagels in *The Cosmic Code* states "There is no meaning to the objective existence of an electron at some point in space, for example, at one of the two holes, independent of actual observation. The electron seems to spring into existence as a real object only when we observe it". (Pagels, 1982, 144) Based on the results of the double slit experiments Niels Bohr, the most prominent proponent of the Copenhagen interpretation, considered that whether you get waves or particles depends on the whole experimental set up including the electrons, atoms or light, the holes, the detector screen and the human observer. If you set up the experiment in different ways (eg one or two slits open, detectors at one or other of the two holes, or no detector at the holes, deciding to have the detectors on or off after the electrons or photons have gone through the holes) you will get different results. (Gribbin, 1995, 14).

An alternative to the Copenhagen interpretation is the "many worlds interpretation" invented by Hugh Everett. The many worlds interpretation presents a view of the universe that involves many worlds (probably an infinite number of them) existing across time and parallel to our own world but totally cut off from it. Everett accepted the existence of wave functions, but instead of the wave function collapsing whenever a measurement took place, a different world would come into existence for each possible outcome of the measurement process. If there are two possible outcomes of a measurement then two separate worlds will come into existence both virtually identical except that one will contain one outcome of the measurement process and the other the other outcome. This involves a continual proliferation of worlds, new worlds continually being created every time an event takes place with worlds branching out from previous worlds like the branches of a tree. Each world is completely separate from all the other worlds and any person in a world will be totally unaware of the existence of all the other worlds. In the Schrodinger's cat thought experiment, instead of there being one cat being neither dead or alive, there are two cats each in a different world, one cat being alive and the other one being dead. The many worlds interpretation has its critics mostly concerning the vast and possibly infinite number of worlds that exist under this interpretation. Amongst them is John Wheeler, Everett’s supervisor and early supporter who now considers the theory has too much "metaphysical baggage". (Gribbin, 1984, 245).

A further alternative to the Copenhagen interpretation is the “transactional interpretation” of quantum mechanics developed by John Cramer in the 1980's. This interpretation involves waves traveling both forwards and backwards in time. The transactional analysis applies to both the double slit experiment and the EPR/Aspect experiment. In the delayed choice double slit experiment a series of single photons goes through the experiment to arrive at a detector screen to build up an interference pattern. However the detector screen can be flipped down to reveal a pair of detectors focused one on each of the two slits. If this is done the photons will be seen passing through one or other of the slits and no interference pattern is produced. The detector screen can be flipped down after the photons have passed through the slits so whether they behave as a wave and show interference or as particles with no interference is actually determined by an event (the flipping down or not of the detector screen) that occurs after the photons behavior has been decided. Cramer explains this as an “offer wave” traveling through both holes of the experiment and if the detector screen is up it is absorbed in the detector screen and causes another “confirmation wave” to travel back, and backwards in time, from the detector screen through both slits back to the light sources. The waves travel through both slits and produce interference on the detector screen. If the detector screen is flipped down the offer wave reaches the detectors focused one on each slit. As each detector is focused on only one slit the confirmation wave that is sent back in time from the detector to the source can travel only through the slit the detector is focused on and as the source can only accept one confirmation wave back at a time, we have the situation where the photons, passing through a single slit, must act as particles.

Cramer's explanation of the EPR/Aspect experiment is that the atom which is about to emit the two photons sends out offer waves in various directions corresponding to various states of polarization. The offer waves are received by detectors who send confirmation waves back in time to the emitting atom. Only if the confirmation waves allow a particular polarization correlation between the two photons about to be emitted will the atom actually emit the photons. This ensures that the polarization of the photons will co-relate as is shown by the Aspect experiment. Otherwise the emission of the photons will simply not take place.

As with all explanations of quantum mechanics the transactional interpretation has its weird features. Quantum waves traveling backwards in time are contrary to common sense and suggests that events may precede their causes. Cramer suggests there may be some effects that may precede causes such as confirmation waves returned by detectors back in time, to a source after having received offer waves, the whole process taking place atemporally. A further problem with the transactional analysis is that it appears to be contrary to notions of freewill in that every photon emitted has its future settled for it.

Squires, in *The Mystery of the Quantum World*, does not come up with a firm answer to the problems quantum theory poses for us. He is a firm realist and accepts non-locality as an essential element in quantum theory in preference to the idea of observers collapsing wave functions.

David Lindley's answer to the one real problem he considers quantum mechanics provides us, the measurement problem, concerns the phenomena of decoherence. Decoherence is the tendency for complex physical systems to move from coherent states to mixed states. He gives the example of fifty yellow peas in a box with one thousand green peas. The yellow peas are in a particular corner of the box but if the box is shaken the peas will become mixed up. Continual shaking will cause the peas to go from one mixed state to another, but there will be almost no chance the shaking will cause the peas to return to their original state with the fifty yellow peas in a particular corner of the box. This shows the tendency of complex macro physical systems made up of vast numbers of quantum systems, such as atoms and electrons, to move from coherent states to mixed states. Continual shaking of the box will simply move the peas from one mixed state to another, but is almost certainly not going to move the peas back to their original coherent state.

Lindley applies the idea of decoherence to the problem of Schrodinger's cat. The quantum state of a cat involves a specification of the state of every atom and electron making up the cat. Whether the cat is alive or dead is not a quantum state, but all possible quantum states of the cat can be divided into one set for the dead cat, and one set for the live cat. The quantum state of the cat, whether dead or alive, is constantly changing as atoms and electrons randomly interact and move around. Lindley also claims we cannot tell from any of the quantum states, whether the cat is alive or dead, but as an empirical fact we are able to tell whether the cat is dead or alive.

Lindley suggests that when the electron spin is measured in the Schrodinger's cat experiment and when the poison is or is not released into the box, the cat enters into a superposition of live and dead states. However as the atoms and electrons are constantly on the move, the superposition will keep changing, the superposition for the live state changing to another superposition for a live state and so on and the superposition for the dead state changing to another superposition for a dead state and then on to another and so on. Over time a vast number of different superpositions will represent both the live and dead cat. To find out the probability of the cat being alive it would be necessary to average all the possible live superpositions of the cat. Equally to find the probability of the cat being dead it would be necessary to average all the possible dead superpositions of the cat. However to calculate the probability of the cat being both dead and alive it is necessary to do a mixed average over both the live and dead superpositions and these superpositions cancel each other out as they completely at random adopt all possible values. This means there is some probability of the cat being alive, some probability of the cat being dead and no probability of' the cat being both alive and dead. The disappearance of the probability of the cat being both alive and dead is caused by the process of decoherence. At the moment of the measurement of the electron spin the cat assumes a coherent alive and dead state but due to the random motion of the atoms and electrons constituting the cat the coherence is lost and the cats quantum state evolves into quantum states that represent a live cat or a dead cat, but not a cat that is both alive and dead. This of course is how we imagine that cats should be. This also explains how measurements can be made in quantum mechanics. Complex macroscopic measuring devices, such as cats, Geiger counters and polarization meters evolve from a superposition of states into particular states from which they are able to carry out measurements of the quantum world.

Quantum logic arises from a belief that the paradoxes of quantum mechanics are caused by our attempt to impose classical logic on the quantum world. If we could find the right logic to use when dealing with the quantum world it may be that the paradoxes will dissolve. The supporters of quantum logic tend to compare quantum logic with non-Euclidean geometry pointing out that our empirical experience of physics has led us to adopt non-Euclidean geometry and equally our empirical experience of quantum mechanics should lead us to abandon classical logic and adopt quantum logic. They claim logic is something we learn empirically rather than something that exists prior to experience. Quantum logic comes in a variety of forms, some saying it applies to both macro and quantum worlds, others suggesting it just applies to the quantum world.

In quantum logic the connectives are the same as for classical logic, but unlike classical logic, quantum logic does not use the distributive law. The use of quantum logic allows mechanical realism; quantum entities exist and they have determinate qualities prior to measurement. Quantum logic can be applied to the paradoxes of the double slit experiment by denying the use of the distributive law in an argument for quantum logic which Gibbins says attempts to dissolve the paradoxes in the sense of avoiding the wrong answer to the double slit experiments paradoxes, but does not provide a right answer to those paradoxes. More particularly, Gibbins considers this solution does not work, even if the distributive law is not used in analyzing the double slit experiment. Gibbins also questions the claim that the connectives mean the same in quantum and classical logic.

On the other hand Gibbins does consider quantum logic to be a legitimate logic which can be applied to the quantum world but not to the macro world. This however still leaves a problem as how to account for the cut between the macro and the quantum worlds. Furthermore quantum logic, so far as it works, does not dissolve the paradoxes of quantum mechanics; they are simply not formulable in quantum logic.

It seems quite apparent that whatever explanation one accepts for the extraordinary behavior of quantum entities one is inevitably required to accept an explanation that seems weird. Quantum logic would appear to eliminate any trace of conventional rationality from quantum mechanics. Quantum mechanics is meant to be a science and the use of quantum logic would destroy quantum mechanics as a science. It is hardly allowable to use a new logic just because the result of experiments seem odd. If quantum logic could be used in quantum mechanics, it is hard to tell why quantum logic or any other logic should not be used in any other area of science and if any logic can be used in any area of science, then you may get results which would destroy any chance of science giving us any understanding of the world. As Heinz Pagels suggests adopting quantum logic is like inventing a new logic to show the earth is flat, when provided with evidence that it is round. (Pagels, 1982, 167). Anything we don't like we just adopt a new logic to get rid of it.

The many worlds theory also has its weird aspects. Countless universes, constantly being created due to quite trivial events, such as an electron going through one slit or another in the double slit experiment or whether a particle tunnels or does not tunnel in the barrier experiment seems weird. Such endless creation of worlds positively invites the use of Occam’s razor.

The transactional interpretation involves waves traveling backwards in time and events preceding their causes. This is obviously contrary to our normal view of the world and seems impossible.

The Copenhagen interpretation itself has obvious weird aspects. The view that an act of observation brings the world into existence, the impossibility of measuring certain co-related properties of quantum entities such as the position and momentum of particles are all contrary to our normal experience of the world. Lindley's decoherence explanation for how we are able to make measurements of the quantum world accepts observer dependence and the uncertainty principle in the quantum world and indeterminism for macro objects for the brief moment before decoherence takes place. His explanation involves all the peculiarities of the Copenhagen interpretation.

It appears all explanations for the quantum world involve weirdness. As David Lindley suggests you can push the weirdness round by adopting one view or another, but you cannot get rid of it (Lindley, 1996, 121, 124). All interpretations of the quantum world are weird in one way or another.

Misunderstandings of Idealist Philosophy and the Observer Dependent Universe

One aspect common to a number of the publications that contributes to the perceived weirdness of quantum mechanics, is a misunderstanding of idealist philosophy and the observer dependent universe. In *The Mystery of the Quantum World* Euan Squires considers that the fact that he can close his eyes and then reopen them and see essentially the same scene shows the existence of an external reality independent of the observer. This does not show there is an external reality independent of the observer. This is what J. S Mill called the permanent possibility of perception. It is perfectly possible that Squires was seeing sense perceptions without there being any independent external reality behind them, both before he closed his eyes and after he reopened them. It simply does not follow from that sense perceptions are consistent over time, to the world that we perceive is an external world, independent of the observer. The world we perceive can still be observer dependent, regardless of it being consistent over time.

He also suggests that because he is able to perceive the same objects with different senses, this shows the objects exist as part of a real world, independent of the observer. This is Dr Samuel Johnson's mistake, as recounted by his biographer James Boswell, when Dr Johnson sought to refute Berkeley's arguments for idealism by kicking a large stone and one supposes getting a sore foot. Coherence among our sense perceptions does not show there is a world independent of observers as it is perfectly possible that the visual sensation of the stone and the foot feeling the stone are both sense perceptions. Adding two sense perceptions, from different senses, together does not equal an independent reality, it just gives you additional sense perceptions. Our senses evolved to keep us alive and as a result they work together to help us avoid predators and to find food. Rotten food, for example, will often look, smell, taste and feel different from good food. Our senses work together to keep us alive, but this does not mean the world we perceive is an external world independent of the observer.

Squires third and fourth arguments concern his perception of other people who appear to be similar to him and that they communicate with him and they say they see very much the same world that he sees. Idealist philosophers would answer that Squires sees other people similar to himself just means that he has obtained additional sense perceptions and that these people say they see a similar world to his merely shows that conscious beings with similar sensory apparatus will obtain a similar view of the world. This does not mean there is an external reality independent of the observer. All the people may simply be perceiving similar sense perceptions because they have a similar sensory apparatus.

Squires considers these arguments naturally point to an external reality independent of the observer and cannot be explained without such a reality. (Squires, 1986, 5-6). However all these arguments are just as consistent with the view of an observer dependent external reality as they are with an independent external reality.

The same mistake is made by Alastair Rae in *Quantum Physics: Illusion or Reality.* He suggests that as different observers agree in their description of external reality, the idea of the physical world not having an objective existence appears unreasonable. He gives the example of people driving cars at traffic lights, where the drivers all receive the same sensory impressions of red and green lights. He suggests that it is much more likely that the lights really exist than by coincidence the driver’s brains and consciousness all change in similar ways so they all stop and go at the right time. (Rae, 1986, 68). This is a false dichotomy. There is another explanation, that as all the drivers have very similar sensory apparatus, they all see the lights in the same way, so they will all stop and go at the right time so there will be no accidents. All the drivers are simply seeing very similar sense perceptions due to the drivers all having a very similar sensory apparatus. The traffic lights argument simply does not mean there is an external reality independent of the observers. It is perfectly consistent with an observer dependent external reality.

A further point of confusion relates to the consequences of giving up the idea of an observer independent universe. Bernard d'Espagnat suggests to do so would trivialize science. It would reduce science "to a set of recipes for predicting, future observation from a knowledge of past ones. Any notion of science "as the study of nature is impossible; nature is a phantom" (Scientific American, November 1979, 139). Such a science could predict all possible correlations of events and still leave the world totally incomprehensible.

David Lindley in *Where does the Weirdness Go?* suggests many criticisms of the Copenhagen interpretation concern the Copenhagenist view that the world is observer dependent. He also suggests that this seems to make the world a matter of our whim and fancy. He quotes Roger Penrose as suggesting that the Copenhagen interpretation will "turn the foundations of science to sand". (Lindley, 1997, 158).

Nick Herbert in *Quantum Reality* considers you could only deny reality if you went all the way and considered macroscopic objects (including measuring devices) were not really there. He considers Berkeley did not believe in the existence of mountains, apples or polarization meters and it is necessary to cease to believe in such macroscopic objects if you want to consider the quantum world to be observer dependent (Herbert, 1985, 236).

One thing needs to be understood. Berkeley did not doubt the existence of mountains, apples and polarization meters. Well maybe polarization meters as they did not exist when he was around. He did however believe in physical objects. Berkeley’s arguments did not relate to the existence of such objects, but to the nature of the objects. Berkeley considered these objects to be mental entities and that they were not composed of matter. It was the existence of matter that he denied, rather than the existence of objects. Berkeley's idea of matter was not the same as that of modern scientists.

A further point is that an observer dependent universe is not a universe of ghosts, phantoms, illusions and randomness. An observer dependent universe can be considered to be a physical, solid, tangible universe with coherence and consistency. Properties such as physicality, solidity and tangibility are given to us by our sensory apparatus, that is how we know about them. The physical properties of objects can be every bit as much a part of an observer dependent universe as an observer independent universe. Anti Copenhagen interpretation and anti observer dependent universe arguments are knocking down a straw man when they imply the observer dependent universe is a random, ghostly, phantom, incoherent world. They are not referring to the real observer dependent universe.

Closing your eyes and then reopening them again to view the same scene and perceiving the same object with different senses and perceiving the same or similar world as other members of the same species equipped with similar sensory apparatus do not mean the world we perceive is independent of us. Modern research into other species' senses make it plain that other species perceive worlds greatly different from the human sensory world and yet their worlds are as valid and true as our world is. Given that we have acquired our sensory apparatus through a process of biological evolution, just as all other species have acquired their sensory apparatus, there does not seem to be any reason to regard the human view of the world as truer or more real than that of any other animal. Animals of different species will each live in different sensory worlds as they all have different sensory apparatus. Each animal species sensory apparatus will be directed at its own ecological niche and are designed to help it navigate, find mates, find food and avoid predators. Each species view of the world will be consistent over time, its senses will work together giving it a coherent view of the world and different animals of the same species will perceive a very similar view of its species world. However each species world will be different from other species worlds and this is a clear example of the universe being observer dependent. This shows how the universe is observer dependent and also consistent over time and with coherence between the senses and with agreement between members of the same species as to what is happening in the world. Each species world would have consistency, coherence and agreement among species members as to the contents and events of the world and yet it is still an observer dependent world.

In the third edition of *Sense Perception and Reality : A theory of perceptual relativity, quantum mechanics and the observer dependent universe* PhilPapers and *Sense Perception and Reality : A theory of perceptual relativity, quantum mechanics and the observer dependent universe* Humanities Commons, on pages 14-15 I state:

“There are millions of different animal species on this planet. Each species sees the same thing in different ways. This suggests there is no single, true, real view of what is being observed and no particular form in which what is being observed, can exist in when it is not being observed. Each of the many different views, different species can have, can only come into existence when an observation is made. Before the observation is made, the particular view seen by an observer is not seen by anyone, so it does not exist. The particular view will continue only for so long as an observer keeps observing. Once the observation stops the particular view will disappear as no other being will see the particular point in space-time in that particular way. This means that things will only come into existence when they are observed and must acquire their properties, such as shape, size and colour, only when they are observed. If something exists independent of an observation, in what form does it exist? The form in which a human perceives it, or the form an antelope, dog, bat, snake, bird, frog or insect perceives it? All these animals will see a particular thing in a variety of different ways and some may not perceive it at all.

If something exists independent of observation, does it have the colours that some animals will see it possessing or colours other animals will see it having, or is it black and white as other animals will perceive it? Surely a thing cannot be of one set of colours and another set of colours and black and white at the same time. The only situation where something can be of alternative sets of colours, or black and white, at the same time, is where it is observed at that time by different observers whose sensory apparatus will give it different appearances. But if there are no observers and no sensory apparatus you cannot have something being of different colours or black and white at the same time. So it is hard to see how anything can exist unless it is observed. What you see may well exist in some form when not observed, but it certainly does not exist in the form in which you see it, as that form is created by your sensory apparatus, and if the sensory apparatus is not working then, what you see ceases to exist.

The arguments given in the previous paragraphs are very strong so I will restate them in a slightly different form. Some animals can see only in black and white, so everything is a shade of grey, others can see in various colours. If you cease to look at something and it continues to exist, what color does it have? The color one species sees it in, or the color another species sees it in? Clearly it can't be grey and have another color at the same time. The same applies to other sense perceptions, a vibration in the air sounds different to different species, the same odour can smell different to different species. Remove the observer, what sound or smell continues to exist? The way one observer hears the sound or the way the other observer hears it? Does an odour continue to exist the way one observer smells it or the way another smells it? Something cannot be of different colors, smells or sounds at the same time. Clearly the sense perceptions a particular observer has disappear when the observer ceases to be making an observation.

The problem is most people have a human centric view of the world and think everything exists in the form humans perceive it and continues to exist in that form when there is no human observer. But there are millions of other views every bit as valid as ours. Why should something continue to exist in the form a human sees it and not in the form other species see it? There seems to be no way we can justify a belief that the human view of the world is so special that it continues when there is no observer, while other species' views of the world disappear.

When we say things don't exist unless observed, it means they don't exist in the human sensory world. They may exist in other species worlds and possibly in other forms quite different from any species world. Our normal ideas of existence are too simplistic; there are multiple ways in which things can exist and multiple worlds they can exist in. The human sensory world is only one such world. Tables, trees and people only exist in the human sensory world when observed with the human sensory apparatus.

Each species has its own sensory world, which are often very different from each other species sensory world. There is some overlap between these worlds but there are many aspects of one species world which will be completely unknown to members of other species. The human view of the world is only one view and is no more valid than that of any other species."

The senses of all animals arose through a process of biological evolution, each directed at a particular ecological niche and they are designed to help us survive and breed. They are not designed to provide us with a true view of the universe as that would involve giving us a vast amount of unnecessary information, not relevant to our survival as a species. There is a cost in terms of energy in providing a perceiver with information about the world around them and as a result only information relevant to survival and breeding is provided by the senses. Information not relevant to species survival within its particular ecological niche is simply not provided and this is an enormously greater amount of information than we obtain through our senses.

The issue as to what effect an observer dependent reality would have is discussed by David Lindley in *Where does the Weirdness Go?* He distinguishes between what he calls weak objectivity (the observer dependent world) where all scientists doing the same experiments will get the same results, and strong objectivity (the observer independent world) where scientific experiments all show the same underlying reality which exists independently of any observation made of it. Lindley notes that weak objectivity is essential to the functioning of science; it is the minimum standard that scientists must accept in order to do their work. Going beyond weak objectivity to strong objectivity is unnecessary, but strong objectivity is an assumption traditionally made in classical physics, but is not demanded by classical physics. The jump from weak to strong objectivity is a leap of faith, rather than of scientific necessity. (Lindley, 1997, 159-161). It seems the acceptance of the idea of an observer dependent reality may not be a disaster for science at all.

Similarities between the Idealist macro world and the Copenhagen Interpretation

The idea of an observer dependent universe can be a positive asset to science. It provides an explanation for many scientific puzzles. The Copenhagen interpretation of quantum mechanics has extraordinary similarities with some idealist interpretations of the macro world as suggested in my papers *Sense Perception and Reality* and the *Philosophy of Perception*. This interpretation of the macro world suggests what is observed depends upon the sensory apparatus used to observe it, the conditions of observation and the point in spacetime that is observed. This seems to be much like Bohr's statements that when observing the quantum world you had to take into account the whole experimental set up, including the observer. Altering the experimental set up is the same as altering the sensory apparatus and conditions of observation in the macro world.

The idealist macro world view that things don't exist until an observation is made seems very much the same as the Copenhagen interpretation view that quantum entities such as photons and electrons only come into existence when an observation is made. Equally properties such as colours only come into existence in the macro world when an observation is made and properties such as photon polarization and electron spin only come into existence in the quantum world when an observation is made. If tables, trees, people and everything else in the human sensory macro world only come into existence when observed, then our observations of the effects in our experiments that tell us of the presence of quantum entities must also only come into existence when an observation is made. How could it be otherwise? as our observations of the results of our experiments are macro level observations seen in our macro level experimental apparatus and come to us via our sensory apparatus. It is not in the quantum world, or the experimental apparatus, that the explanation for quantum entities only existing when observed can be seen. It is the way the human sensory apparatus creates the human sensory world that causes quantum entities, as shown by the effects in macro level experimental apparatus, to come into existence and acquire their properties. This may possibly solve the quantum measurement problem.

Perceptual relativity is the idea that the world appears different to different observers. Perceptual relativity, as suggested in my paper *Quantum Measurement Problem: Collapse of the Wave Function explained*, applies in the macro world but wave/particle duality suggests it also applies in the quantum world and complementarity is arguably just another name for perceptual relativity.

The veil of perception in the macro world is the problem that we are unable to get past the limitations of our senses to see how things really are. The uncertainty principle in the quantum world looks very much like an example of how we cannot get past the veil of perception. There are limits to what we can perceive in both macro and quantum worlds so the veil of perception can be considered to apply in both worlds.

In quantum theory we are often considered as only obtaining a snapshot by snapshot or observation by observation view of the quantum world. This is a view without any continuity which is considered to be different from the macro world where we have continuity. In the macro world we see by reflected light, by photon after photon which gives an appearance of continuity, but is not really continuous. We get a view similar to watching TV which appears continuous but we know can be slowed down to a frame by frame view where we can see there is no continuity. The appearance of continuity in the macro world, sometimes known as the persistence of vision, is caused by the workings of our sensory apparatus which gives apparent continuity, but in reality photons reach our sensory apparatus one by one so there is discontinuity in the macro world as well as the quantum world, even though in the macro world the discontinuity is hidden from us.

The external points of reference Bohr considered we have in the macro world such as space, time and causality are just creations of our sensory apparatus and a different sensory apparatus would not have available those points of reference. General relativity shows space is a different shape for different observers, special relativity shows time passing at different speeds for different observers and it is never possible to prove causality. This means that both the macro world and the quantum world exist without any external points of reference and both are observer dependent and there is no need for a dividing line between the two worlds.

The Copenhagen interpretation has long been the orthodox view of the quantum world and this is not surprising considering how weird the alternatives are. However realism has usually been assumed in the macro world as shown by some of the books referred to in this paper. But, given modern research into animal senses, neurology and cognitive psychology, realism must inevitably cease to be a serious explanation of the macro world. It seems quite obvious the macro world is observer dependent and the orthodox interpretation of the quantum world postulates an observer dependent world as well. This suggests the same rules can apply to both the macro and quantum worlds, which eliminates the need for a dividing line between the two worlds.

The first paragraph of this paper suggested the quantum world was weird and not really understandable. This is because we tended to compare it with the macro world and it seemed very different from the macro world. But we have misunderstood the macro world and when we come to understand the macro world as an observer dependent world, the quantum world does not appear weird at all.

The debate between an observer dependent world and an observer independent world is analogous to two debates in the history of astronomy. The first debate was between the geocentric and heliocentric views of our solar system. The geocentric view was the intuitive common sense view as the Earth was obviously not moving according to our human senses. However if you dig deeper and look at all the evidence you will find the Earth is moving, both orbiting the Sun and spinning on its axis. The same situation exists with the observer dependent or independent external world. The common sense intuitive view is of a world independent of the observer, but if you dig deeper and look at all the available evidence the world we observe is clearly observer dependent.

The second debate concerns the shape of space and the passage of time. The intuitive common sense view is that we live in flat three dimensional space as was believed throughout human history until the twentieth century. However if you dig deeper and look at all the available evidence you find in accordance with general relativity we live in a world of four dimensional curved spacetime. The intuitive common sense view of time is that it passes at a steady and consistent rate but if you dig deeper you find that in accordance with special relativity and time dilation, time varies with the speed of the observer.

The idea the world is observer dependent is quite counter intuitive but the evidence we have supports it. An examination of the way other animal senses work and the recognition that their worlds are different from ours but are just as valid and true as ours inevitably leads to the conclusion the world we observe and live in is observer dependent.

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