Opinion and Perspectives

The Measurement Problem in Quantum Mechanics: Well, Where's the Problem?

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ABSTRACT

The most discussed thought experiment in quantum mechanics (QM) is the one of the dead+living cat, which sets out to explain what is known as the *measurement problem*. Since the first years of QM, and despite various arguments, the widespread beliefs of the past few years have tended towards including a conscious observer in the act of measurement. Various different opinions have been expressed on the measurement problem by various schools of thought and leading physicists, but none of them has been decisive. Especially, the introduction of an observer (human-brain-consciousness-mind-intelligence) carrying out measurements into the experiment or into the setup of the experiment has led to even more complex problems. Today also, new solutions are being put forward. This article deals with the thought experiment of Schrödinger's cat and suggestions for alternative solutions by introducing a conscious observer.

Key Words: measurement problem, superposition, observer, consciousness, mind, wavefunction collapse

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Introduction

The formation of scientific method started in 16th-century Europe, and after that went through a huge revolution. The universe ceased to be mysterious and beyond human understanding, and started to be understood as having a mechanical quality. In the wake of Copernicus' theory, the Sun and the Earth and Man were no longer seen as the centre of the universe, but as only one planet of many at the edge of the Galaxy, orbiting in a very unremarkable area. The human-centred universe had disappeared, and this caused great disillusionment. But today's physics has placed man right back at the centre of the universe (Hodbhoy, 1992). For many years it was accepted that an experiment with the same starting conditions would always give the same result, that the experimenter has no role to play in this, and that the physical world had a physical reality. However, quantum mechanics (QM), which was developed in the 1900s, has a completely opposite view in this regard. It has very different things to say about the ordinary and common place.

For this reason many problems arise with regard to measurement. Are we to abandon the method of scientific enquiry which has until now been the basis of science? What will take the system out of a superpositional state and reduce it to a permanent reality? Wigner's friend? A cat? If this is the result of a conscious brain, then how do we know that the cat is not conscious? Or does the hammer in the box along with the cat enable us to arrive at a definite conclusion? Does a tree falling in a forest where no one has been make a sound? Is the Moon there when no one is looking? Is there a problem with our basic principles if none of the results derived from principles which are not explicit are themselves not explicit? When we have correct principles and we follow them, if a day comes when we confront a totally different reality, where is that reality? Are we facing a problem which Descartes described in the 17th century?

> "If we want to examine philosophy and bring all the realities that we know firmly out into the open, it is necessary first to escape from our prejudices, and until we can review all the truths or beliefs which we previously held, to hold them as false. After this, to examine anew the theories in our minds." (Descartes, 1644).

Considering this statement, is it because we have not completely escaped from our

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previous philosophical ideas that we cannot interpret properly the philosophy of quantum mechanics? Then presumably the time has come to take our brain in our hand and squeeze it out like a sponge in order to leave aside the old thoughts which still exist in the depths of our minds. Being bound to the old philosophy is like a kind of ball and chain. It stands as an obstacle to our understanding the new ideas which QM has given birth to. If we use our intelligence as we should, it has the capacity for correct thinking and achieving the highest knowledge, and so there is no reason why it cannot solve this problem.

In order to sort out the problem of measurement in QM, it is first necessary to understand from where the basis of the problem arises. Finding the point of origin of the problem is tantamount to solving the problem. Therefore let us review the possible problem areas.

1. Inadequacy of the language used

It is not possible to think of scientific language separately from science or language, and the most important component of scientific language is terminology. Technical terms are generally words which represent concepts, objects, events or states in the fields of arts or science, and which have definite, single and specific meanings. It must not be forgotten that science is not independent of the language of the age. Every kind of thought and feeling including science can be expressed in language, and therefore the true force of a thought only exists in languages which have reached a high state of maturity. It is only possible for our knowledge to reach scientific quality with a language as a common means of expression. Words are in reality labels attached to things. Of course it is impossible in reality for a complete equivalence between words and things, because it is impossible to find a separate name for everything in the universe. In this way names are given to things according to their shared characteristics, ignoring points which they do not have in common.

When we look at the relationship between a word and an object, we see that the relationship between the concept and the word is definitional because it constitutes the label for the concept, and that the relationship between the concept and the object it carries a causality arising from observation and forming outside of ourselves. The object and the word are joined together by means of the concept, and this relationship is conventional and dependent on accepted common and habitual usage. A word is the name of a concept and a concept is the meaning given to a word (Yalgın, 2004).

Werner Heisenberg says *"The thing which we observe is not nature itself; it is the answer which nature gives to the question which we ask."* The mechanism of measurement is something created by the observer. The thing on which he makes his observations is not nature itself but nature as affected by the way the question was framed. To agree with Bohr's statement, we are both spectators and players (Heisenberg, 1930; 2007). Heisenberg may not have mentioned consciousness itself directly, but in one way he suggested that the result of an experiment was dependent on the observer's consciousness and a whole set of neurophysiological mechanisms.

Heisenberg's uncertainty principle introduces a distinction between macro and micro. The ψ-psi function cannot be dependent on two related dynamic variables such as space and momentum at the same time. This principle has brought a limitation such as not being able to use together certain quantities to characterize the physical state of microuniversal objects. In addition to this limitation, linguistic expressions which express the characteristics of macrouniversal objects are used to characterize the state of microuniversal objects. The disparity in the use of language is this: how is it possible to talk about the microuniverse using terms of classical physics which are not adapted to quantum mechanics? Is it possible to describe the microuniverse with the linguistic terms of the macrouniverse? Describing the microuniverse using the linguistic terms of the macrouniverse is one of the principles of the Copenhagen interpretation (Heisenberg, 1930).

One of the main problems with observation is the use of language in QM. For this reason, it is wrong to resist the cascade on rigid principles. Language can be expected to develop by itself and in time fit itself to new situations. We saw this previously with the theories of General and Special Relativity, but with time the problem was solved. However, the most intractable linguistic problem of all of these is in QM, and its solution will not be easy. This is because "*Normal everyday language concepts are not of a kind to apply to the structure of the atom*" and we do not have in our hands a guide to equate the concepts in language to mathematical symbols.

We are not in a very different situation from what Descartes noticed many years ago about the language which he used:

> "In order to define concepts with our own mouths, we attach them to various words and we mostly remember those words rather than the concepts. Thus, when we separate the thing we are conceptualizing from the words which we chose to express it, we cannot understand anything easily or clearly. In this way most men pay more attention to words than to things, and so most of the time they believe in concepts which they do not understand, and they do not much understand about understanding." (Descartes, 1644).

Heisenberg states that the law specific to language of *"tertium non datur"* (the Law of Excluded Middle, also known as the principle of excluded middle or excluded middle or excluded third) must be changed. This is because, as classical logic accepts, if an argument carries a meaning, then either the argument itself or its negative must be true. Thus, of the statements "there is a book in front of me" and "there isn't a book in front of me", either the first or the second is true. There is no third possibility. This is also true for the phenomenon of tunneling. An object is either on the left or on the right – there is no other state. Or a ball is either grey or it isn't. In other words, an object either has a characteristic or it doesn't. But in QM there is another state: that of superposition. We have a red ball and a blue ball. But QM argues that a state of superposition is created and a grey ball which no one can see exists. Richard Feynman touches on the same topic when he asks, "In quantum language, I wonder if there is a finite number of 'letters' to write the 'words' and 'sentences' which when put together would describe almost all events in nature?" (Feynman, 1988). It can be seen that a new language is needed for QM, and we must use this new language to resolve the conflicts with our intuition. But how is this to be? Physicists and philosophers are endeavoring to achieve this.

Attempts to Form a New Language

With the help of modern microphysical methods we are able to observe atoms and the particles of which they are composed. However, we cannot compare this observation experience with an experience of daily life. Information obtained in this situation is not the result of direct sensory perception. Our everyday spoken language and words, which relate to the world of our senses, are not at all sufficient to describe sub-atomic phenomena and observations. This is an observation outside our normal five senses. The structure obtained is mathematical, and the equivalents to state and describe this are not found in normal language. Then what must we do? We must create a suitable language.

Physicist David Bohm (1917-1922) introduced and attracted some attention with an alternative language relating to philosophy and psychology (Bohm, 1980). Bohm's idea related to the subject-verb-object sentence structure of modern languages. In this classical structure, the transitive verb crosses the space between the subject and the object. But in some ancient languages, for example Hebrew, the verb takes first place in the sentence. In fact the characteristics of this new language which Bohm tried to create are also present to some extent in Arabic.

Bohm called this new language *Rheomode* (from *rheo-* 'to flow') and developed a new structure of language (Table 1). "*The primary movement in our thoughts is inserted into the structure of language and what plays the primary role is more often the verb than the noun*" he says. Starting from this, he produces words with different meanings. The use of this new language is a way to enter quantum mechanics, cognitive states, and 'the country of consciousness and truth'. Bohm's language relates to perceptual and cognitive activities. This rheomode specializes each word as a view of the movement of consciousness. However, if the whole of reality is this, can we express the total of things, thoughts and words? Bohm offers the following:

> [...] one of the best ways of learning how one is conditioned by habit (such as the common usage of language is, to a large extent) is to give careful and sustained attention to one's overall reaction when one 'makes the test' of seeing what takes place when one is doing something significantly

> different from the automatic and accustomed function (Bohm 1980; p.28).
>
> [...] to see the relevance or irrelevance of a statement is primarily an act of perception of a very high order similar to that involved in seeing its truth or falsity. In one sense the question of relevance comes before that of truth, because to ask whether a statement is true or false presupposes that it is relevant (so that to try to assert the truth or falsity of an irrelevant statement is a form of confusion), but in a deeper sense the seeing of relevance or irrelevance is evidently an aspect of the perception of truth in its overall meaning. (Bohm, 1980; p.33)

One can further develop this idea by citing another passage from the book under discussion:

> [...] it is not right, for example, to regard the division between relevance and irrelevance as a form of accumulated knowledge of properties belonging to statements (e.g., by saying that certain statements 'possess' relevance while others do not). Rather, in each case, the statement of relevance or irrelevance is communicating a perception taking place at the moment of expression, and is the individual context indicated in that moment. [...] when relevance or irrelevance is communicated, one has to understand that this is not a hard and fast division between opposing categories but, rather, an expression of an ever-changing perception, in which it is possible, for the moment, to see a fit or non-fit between the content lifted into attention and the context to which it refers. (Bohm, 1980; p.34)

Another attempt to create a new language was made before Bohm by Jacques Derrida (1930-1976). Influenced by Martin Heidegger (1880-1976), he agrees with the idea that language is not a thing which belongs to people, but people are something belonging to language. In one sense, language speaks through people, and language expresses thoughts. Developing his ideas along these lines, Derrida suggests that Western philosophers do not understand how dependent their thoughts are on language. He comes out against a separation between spoken and written language. While speaking is the direct embodiment of thought, writing is a secondary indicator of speech. And according to Derrida, "*there is no ideal language for the expression of all thoughts*".

The effort to create a new language artificially is from one viewpoint a paradox. A language which allows us to transfer our thoughts to each other is an accumulation of millions of years and millions of people. The attempt to jump over this accumulation and develop a language which will express thoughts and concepts better is a bit like a person trying to jump over his own shadow. Can a person jump over his own shadow? Even if he can't, he can change the shape and size of it by twisting and turning and changing direction. In this way the attempt to create a new artificial language seems at first sight to be meaningless.

2. System Information

The meaning of measurement is information. The term 'information' is used not only in neurology, but in many other disciplines. Each concept has the same meaning. Information in one sense is another expression for entropy. Information has a meaning 'for us'. It shows that meaning has emerged inside a concept created by an intelligent being. Superposed states contain pieces of information which carry meaning and importance for physics. Information, while dependent with regard to meaning and importance on the measurement device, by which it is measured, is connected to the observer and the observed which make up the system as a whole. The meaning if this information cannot be expressed by the grammar of a language or by linguistics. Information, like superposition, is holistic and can change instantaneously. It's like the picture which can be two things at the same time. Heisenberg's uncertainty contains a kind of information too. This principle prevents access to information about both speed and position at the same time. Obtaining information on one of them causes us to give up the other one (von Lucadou W, 1995).

One if the most important differences between classical physics and QM is information loss. A classical system contains much more information than a quantum system. This is because classical variables can take any value, but values in a quantum system take discrete values. In order to change a classical system into a quantum system, information must be lost. For this reason nature prefers to behave in a classical way at many levels. It tends to increase its entropy.

Table 1. Some new words and their meanings from the new language (*Rheomode*) created by David Bohm (1980).

To levate	the spontaneous and unrestricted act of lifting into attention any content whatsoever, which includes the lifting into attention of the question of whether this content fits a broader context or not as well as that of lifting into attention the very function of calling attention which is initiated by the verb itself.
To re-levate	lifts certain content into attention again, for a particular context, as indicated by thought and language. The prefix *re-* signifies a new occasion of 'to levate', as well as similarity between the two occurrences — of levating some content and re-levating it. But the re-levated content should not be considered to be simply identical, because it implies time, another occasion which cannot only be similar to the first one, but is also different; To re-levate is re-levant = to enact a perceptual act proving whether the content lifted again fits the observed content. When this perception reveals a fit we are entitled to say that 'to relevate is re-levant'.
To re-levate is irre-levant	when the act of perception discloses actual non-fit of the content lifted again to the context in question we say that 'to re-levate is irre-levant'.
Re-levation	a continuing state of lifting again and again a given content into attention.
Irre-levation	to continue with a state of re-levation where it is irre-levant to do so or doing that from the very start. With other words, inappropriate could be either the first act of relevating and next this state is continued because of an inability, c, and/or desirability of being in the state of irre-levation, or re-levation can turn into irre-levation because of a change of the internal and/or external context of use of the mental content while, being inattentive to the actual change, we continue to lift through the application of our attention a habitual pattern to match the stimuli.
Levation	a sort of generalized and unrestricted totality of acts of lifting into attention (Bohm1980: 35).
For the formation of the second paradigm is taken not without good motivation the Latin verb videre meaning "to see". The root verbal form in the rheomode for "seeing" will be 'to	
To vidate	calls attention to a spontaneous and unrestricted act of perception of any sort whatsoever, including perception of whether what is seen fits or does not fit 'what well as perception even of the very attention-calling function of the word itself;
To re-vidate	to perceive a given content again.
To re-vidate is re-vidant	if this content is seen to fit the context of use, we can to confirm that;
To re-vidate is irre-vidant	if this content is seen not to fit the context of use we are entitled to say: 'to re-vidate is irre-vidant';
Re-vidation	is a continuing state of perceiving a certain content;
Irre-vidation	is a continuing state of being caught in illusion or delusion, with regard to a certain content;
Vidation	is an unrestricted and generalized totality of acts of perception (Bohm 1980: 36-37).

The meaning of information and amount of information are different, just as in language. Claude Shannon's (Shannon and Weaver, 1949) viewpoint on information is impractical for the evaluation of meaning. It merely quantifies information as 'bits'. Thus, what is the meaning of a piece of data 950 Kbytes in size? How can we find the meaning of that information? Meaning is expressed in effects and results which are caused. This information is called Pragmatic Information (PI) (von Lucadou W, 1995). The meaning of information which reaches us (a phone call or a piece of news in the newspaper) makes itself known by the reactive changes which it causes in us. Even when the amount of information in bytes is the same, its meaning and the reaction to it may be very different. The meaning of a 950 Kbyte picture downloaded from the internet and the reaction which its content causes in you are related; instead of a jpeg, it might be a music mp3 or an video mpeg: in each case the amount of information is the same, but the content and the meaning are different, and our emotional reaction to them will be very different (Shalizi and Crutchfield, 2001).

In order to explain the characteristics of PI, Weizsacker (1972; 1974.) put forward the idea of a relationship in the form of 'novelty' and 'confirmation'. According to this, PI must carry novelty and must be confirmed. PI is a product of these two dimensions. A newspaper written in a language we do not know carries novelty for us, and does not express any meaning to us (it does not contain PI). In the case of a newspaper in our own language that we had read the previous day there is no question of novelty, we only glance at the paper quickly and reaffirm the information from the pages which we gained yesterday. PI is at its highest level when novelty and confirmation are at a medium level (50%-50%). Novelty and confirmation are in an inverse relationship. As novelty increases, the level of confirmation decreases and as the level of confirmation decreases, so novelty decreases (Figure 1 and 2).

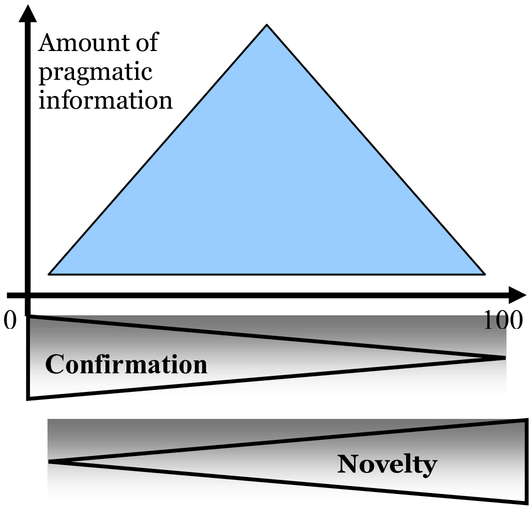

Figure 1. The relation between pragmatic information, affirmation and novelty. The Figure illustrates the property ii) above, the non-monotonic dependence of pragmatic information on novelty (randomness) and confirmation. This is also characteristic for measures of complexity.

Observation carried out in QM must be included in PI. There is a piece of information obtained by observation in the result. Before observation, the wave function is in a free and independent state. Like an unobserved object, rather than being located in one certain place, it is found at the same time in many possible places. It is at the same time everywhere and nowhere. This state represents the mixture of autonomy and dependability at different levels. But when the system is put into an experimental mechanism in order to observe it, its independence is constrained and the dependability of how it will behave increases. However, at the same rate as its autonomy decreases, an inevitable change takes place in the system. When it is observed or viewed, many possibilities condense into one. It freezes as a small object. At the moment of these transformations, there is a change in the parameters of autonomy-dependability. There is a change in both the quantity and meaning of PI values of the system. Therefore it is necessary to include PI in the system which is observing and being observed.

This can be explained by comparing it to the examination of a crow. If you want to examine the behaviour of a crow in its natural surroundings, its independence will be at a maximum. If you put it in a cage its autonomy will decrease, and it will not behave as it should: its dependability will decrease. On the other hand, if you nail the crow to a lab bench and take its internal organs out to examine them, your observations will be at the highest level of dependability, but there will be no autonomy left, and the crow will show no behaviour (von Lucadou W, 1995). In this case, we the observer and experimenter have changed the results by the way we set up the experiment according to our expectations, and thus have changed the PI.

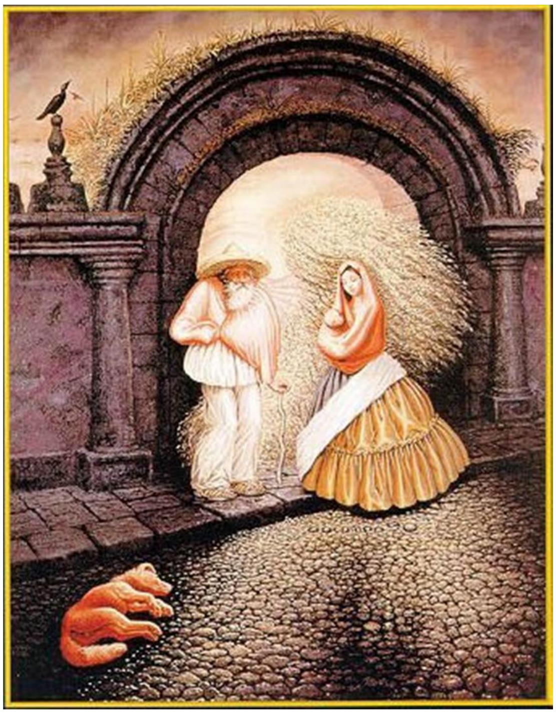

Figure 2. Our perception plays an alternating illusion on us, and sometimes we see a white-haired old man, and sometimes a man, a woman and a dog on the street. The structure of the picture does not change, but the information which we derive from it keeps changing.

3. The Problem of the Experimental Apparatus

Uncertainty in Quantum Mechanics

One of the important differences in viewpoint between the understanding of classical physics and that of QM is that of certainty. In the view of classical physics, any two physical magnitudes can be determined simultaneously and with any desired accuracy. If the position of a particle, its speed and the forces acting on it are known at a given moment, its position and speed can be known at a later moment. For this reason it is deterministic (Dereli and Verçin, 2000). In QM however, it has been found that the energy-time and momentum-speed pairs cannot be measured simultaneously with any desired accuracy. This is one of the main concepts which Einstein took as a defect in quantum theory. This was because Einstein thought that '*God doesn't play dice*', and that he would not have allowed uncertainty. This principle at first sight shows that nature has removed determinism. But in fact, looked at closely, it seems that this is the most basic element gradually showing nature's microdeterminism.

Uncertainty can be in two forms: either the uncertainty arising from the large number of bodies, or uncertainty despite there being only one body. Uncertainty arising from many bodies arises from them displaying behaviour (coordinates) of a kind which is unpredictable because of the multiplicity of the interactions between them. This is not because of the slipperiness of the coordinate itself, but because of the large number of other elements in the system affecting it, that a moment cannot decide on a value. This uncertainty is subjective, and partly stems from our lack of knowledge about the system. If we knew how each element behaved and the complex interactions coming from that behaviour, there would be no subjective uncertainty. For example, if there are 10-15 dodgem cars on a track at a funfair, we cannot totally determine the movements of the cars in advance. With the collisions with their surroundings, they will acquire new positions and directions, and their orientation will change further with the driver's wishes and knowledge. In this situation, a general and approximate conclusion can be reached by statistical methods (Badii, 1991). In the case of uncertainty involving a single body, however, it is influenced by events not from outside, but from within itself, from its own nature. The internal organization of the object is in a structure which an informed subject cannot reach. Subjectivity ends here and objectivity comes into play. This is what is in QM. From now on it only involves probabilities.

It has been understood that in QM conceptual pairs relating to position cannot be measured simultaneously with the desired accuracy. These conceptual pairs can be put in three groups: position-momentum, energy-time and angular momentum-angular position. Werner Heisenberg proposed in 1927 that these pairs of variables would not both be determinable simultaneously with the desired amount of precision. He showed that the product of the errors in the determination of the two variables could not be smaller than $\hbar=h/2\pi$. And from this came the Heisenberg uncertainty principle in QM. This can be expressed in this way for various pairs:

For position-momentum	$\Delta x \bullet \Delta p \geq \hbar$
For energy-time	$\Delta E \bullet \Delta t \geq \hbar$
For all positions and momentums	$\Delta q_i \bullet \Delta p_i \geq \hbar$
For angular change of place and momentum	$\Delta \theta \bullet \Delta L_\theta \geq \hbar$

where • is multiplication and i = x, y, z; θ is angular change of place, L_θ is angular momentum, E is energy, t is time, p is momentum, q_i is general spatial coordinates q_x, q_y, and q_z, and p_i is general momentums p_x, p_y, and p_z.

This equation has this meaning: it is impossible to know or to measure both the momentum and the position of a particle at the same time. That is, as information on one of the special variables characterizing the behaviour of a particle increases, so information on the other is reduced or becomes uncertain. We cannot measure and specify the two at the same time with the degree of accuracy which we desire. In this situation we have to make a choice between showing coordinates or momentum (Stengers and Prigogine, 1997). Another thing which can be understood from the equation is that the product of the uncertainty of the particle's position and momentum are at least equal to the Planck constant. This equation says that with whatever certainty we define the position, the momentum will be that uncertain to the same extent. A definite measurement of momentum will increase the uncertainty of the measurement of position. Because of this spatial uncertainty the particle can be in any corner of space. If we had measured the position with infinite accuracy, momentum would be completely unknown, and *vice versa* if we had measured the momentum accurately, the position of the particle would be completely unknown. For these reasons, both the position and the momentum of particles in nature must remain partially unknown.

The uncertainty principle is accepted as effective on only microuniversal scales because the Planck constant is a very small value. For macrouniversal objects with weights expressed in grams, measurement accuracy of position is 10^{-6} meters, and according to the uncertainty principle its speed cannot be measured better than 10^{-25} m/sec. But for an electron in an atom, if we consider that the diameter of an atom is 10^{-6} meters, the uncertainty is 10^{6}m/sec. The meaning of this is that an electron can be anywhere and everywhere at any moment! If spatial variability (Δx) is around 1 cm, momentum variability (Δp) is 10^{-27} gr.cm/sec. This deviation is unimportant for classical physics and can be accepted as zero for practical purposes. However, if $\Delta x=1$ angstrom, Δp will be 10^{8} times this value, and a serious uncertainty occurs in a microuniversal system.[16] As a result, QM limits our capacity to determine position for microuniversal objects. For each particle there is a minimum mass. The position of an electron cannot be defined to a distance less than 300 fermi (1 fermi=10^{-13} cm): this value is 1% of the radius of a hydrogen atom.

Peter Janich (2008), in experiments in the natural sciences, makes an assessment from the point of view of the observer. According to Janich, the flow diagram of any experiment is in this form: $S_0 \rightarrow a \rightarrow S_1 \rightarrow P \rightarrow S_2 \rightarrow E$. All of these are called 'obligatory information'. Here, each action and experiment begins with the initial conditions of S_0. Under the influence of experimental action a, the experimental apparatus S_1 comes to a final state S_2 through the system's own dynamics. S_2, the experimental data, contains E, the result. E (information) is in principle a part of the system S_2. The smallest change in S_1 will have an effect on the rest of the system. The expectations of the experimenter may have an effect on the experiment on this flow chart. A here represents a defined piece of pragmatic information.

In classical physics and QM, the macroscopic environment is a system composed of two basic parts. The first of these is the macroscopic conditions which remain outside the measurement apparatus and define the independence of the state of the particle as independent of the measurement apparatus. The second is the measurement apparatus. Macroscopic conditions are not affected by energy-momentum exchange at the time of measurement, although the same is not true for the measurement apparatus. It interacts with the characteristics of the microuniversal particle such as position, speed and momentum which are carried into the macrouniverse, and records the measurements.

Brain, Mind and Uncertainty

Heisenberg's uncertainty principle makes possible, obligatorily, the simultaneous measurement of space-time (x, t) and momentum-energy (p, E). For this reason, quantum measurement devices must be divided into two groups: 1. Space-time measurement devices and 2. Energy-momentum measurement devices. If an example is needed, a space-time measuring device shown by Aq corresponds to a position at a point in space of the form $\Re$(q). A momentum-energy measurement device measured by Ap measures the momentum $\Re(p)$. A measurement made by a quantum mechanical measurement device of the form $\Re(p$, q) is impossible because of Heisenberg's uncertainty principle. Separating the measurement devices into two causes the macroscopic environment to be divided into two also (Koç, 1983):

Macroscopic Environment (space-time) = Macroscopic conditions + Aq(x, t)

Macroscopic Environment (energy-momentum) = Macroscopic conditions + Ap(p, E)

QM talks about 'knowable' rather than 'real'. Heisenberg defines the knowable as a quantum information field. The quantitative dimensions of position and momentum represent the extension of a spectral width. They cannot be thought of as 'real' or 'completely correct' in a definite sense. When dimensions are simultaneously measured for a particle such as space and momentum (x, p), energy and time (E, t), the exact measurement of one dimension makes the other extend to infinity. In other words, in the case of the 'real' momentum of a particle being shown completely (Δp=0, where the amount of momentum change is zero, that is its value is completely known), according to the uncertainty principle the position in spatial dimensions is infinity ($\Delta x \rightarrow \infty$), that is, it is 'everywhere' at the same time. From another perspective, if the energy of a system is measured completely (ΔE=0), it will show an infinite extension in time ($\Delta t \to \infty$). As stated previously, the product of change in momentum Δp and variability in position Δx are equal to or greater than the Planck constant. Uncertainty limits and extensions beyond knowable states make it impossible for us to perceive physical reality consciously. Even so, physical states may be superposed, and this is also outside our perception (Bernroider, 2003).

We experience separately the mental similarity characteristics ($\Delta t \to \infty$ and Δp=0) and the material similarity characteristics ($\Delta x \to \infty$ and ΔE=0) related to these. Experiencing both at the same time is impossible. But in real life we do not experience our physical (matter) and mental (mind) states separately but as a whole in a single construct. All our experiences occur within space-time, and their distributions cannot be simultaneously zero (Figure 3 and 4).

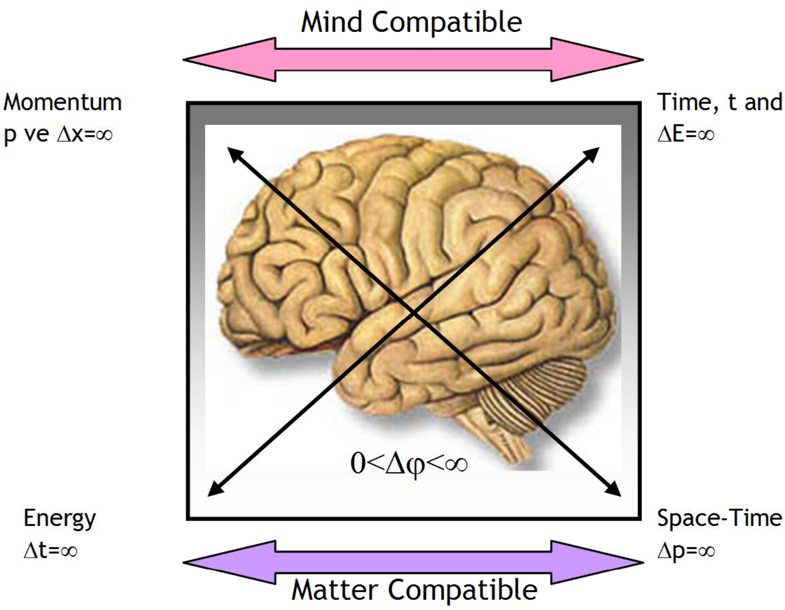

Figure 3. The brain is physically in two separate states: the physical brain and the mind. Everything we experience is contained in space-time. Their physical distributions and dimensions can be seen in the figure. The brain stands opposite the mind. The transit field forms the (knowable) physical brain in the infinite dimension Δφ. This is between zero and infinity: $0<\Delta\varphi<\infty$. The two sides, mind and matter, show a compatibility in magnitudes. The incompatible magnitudes (momentum vs. location, energy vs. time) are on the diagonals. These incompatible magnitudes (the diagonal arrows) bring about a mixture of the internal characteristics of mind and matter.

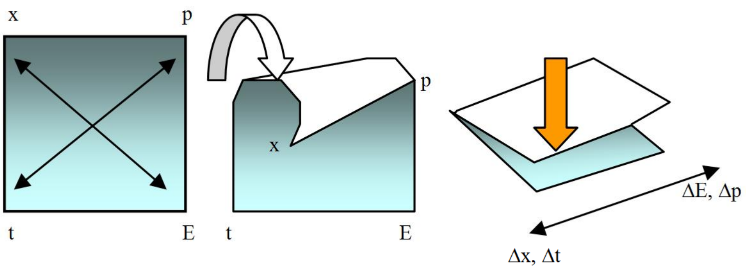

Figure 4. This figure can go a step further. The brain can be folded according to the foursome of space-time-energy-momentum. By folding, the 'knowable' and the 'real' can be brought into an equal state. Incompatible magnitudes approach each other on a single dimension. The brain 'transits' between these two suitable states. Consciousness shows coupling with only one direction: from E→*p* towards *x*→*t*.

4. Are We Observers or Participants?

The only thing which can be stated quite clearly is that we are faced with a tangle of relationships taking in the observer and the observation process and indicating the complexity of the system, or in other words the relationship. What can be understood from all the alternative interpretations is that it is not possible to ignore the observer, whether conscious or not. A QM which brings in an observer cannot be saved by quantum theorists alone. For a suitable solution, a combined approach from various fields of science will be necessary.

John Wheeler saw it as suitable to use the expression ‘participant’ instead of ‘observer’, and took the effect of consciousness to an extreme and different conclusion: he said,

> “In order to explain what is happening, it is necessary to eliminate the old word ‘observer’ and replace it with a new word, ‘participant’. It is strange but in one way the universe is a participatory universe.”

In 1990, Wheeler has suggested that information is fundamental to the physics of the universe. According to this 'it from bit' doctrine, all things physical are information-theoretic in origin (Wheeler, 1990);

> “It from bit. Otherwise put, every 'it'—every particle, every field of force, even the space-time continuum itself—derives its function, its meaning, its very existence entirely—even if in some contexts indirectly—from the apparatus-elicited answers to yes-or-no questions, binary choices, bits. 'It from bit' symbolizes the idea that every item of the physical world has at bottom—a very deep bottom, in most instances—an immaterial source and explanation; that which we call reality arises in the last analysis from the posing of yes–no questions and the registering of equipment-evoked responses; in short, that all things physical are information-theoretic in origin and that this is a participatory universe.”

Whether the device performing the observation is a physical apparatus or a human sensory mechanism, it has to follow the laws governing classical dynamics or quantum dynamics. Wolfgang Pauli (2001) also used a similar expression:

> “A thing forms in reality only when it is observed and in connection with the observation… entropy increases. Nothing occurs between observations.”

A lot of the difficulty of QM comes from the division between *endophysics* and *exophysics*. In endophysics and exophysics, we all accept that the observer is a part of the observed world, but that whether humans are observing it or not, the world still exists. An external point of view keeps the observer and the observed separate from each other. An internal viewpoint includes the observer in the system. In the concept of endophysics, the observing and the observed are closely related. Normally if we are a part of nature, when we are defining nature we accept it as our object. From this viewpoint, while nature remains relatively still, we disturb it by observing (*asking questions*):

> “A completely closed system without an observer is an internal system. If this internal system is divided into an observer and an observed, that means we are characterizing it as an external system. In that case the world of the observer and his means of communication are characterized as the external system… Quantum exophysics relates to the ontological side of the quantum concept, and quantum endophysics relates to the epistemic side. Endophysics follows universal laws and characterizes objective reality, that is, that which is independent of humans and their observation; exophysics deals with perception, observation, measurement and evaluation. Exophysics is looking for the existence of an experimenter, an observer, and a system of measurement as conditions. In quantum endophysics, on the contrary, there is no such thing as the object-subject division, and so endophysics is concerned not with measurement but with existence… The internal world, before we observe and evaluate it, presents itself to the subject and the measurement device as a whole.”

If the observer has such an effect, what would happen if we eliminated the observer? What would happen to the cat experiment if there was no direct observer and we made recordings on photographic plates? That is, could we do the experiment if there were no conscious human being involved? Imagine we have a plate with two slots, and that an electron passing through one slot or the other is photographed by an automatic system. The photographic film has no conscious mind and will not collapse the wave function by observation or perception. For this reason a superposition of two different views forms on the film. Let us make copies of this film without a conscious person seeing it, and post it to two separate people. One of the people who receives the letter opens it and looks at the film, and causes a view reduced to one - a collapse - of the superposition choices. At that moment all the superpositions in the hand of the person who received the other letter disappear. Here, distance is of no importance. If one person is on the Earth and the other is on the Moon the result is the same because of quantum entanglement. However, it is not always right to say that the microuniversal processes are always carried into the macrouniverse by an observer, as discussed above. There are events in nature of radioactive decay which start by themselves and which are carried to the macrouniversal world by themselves, independent of an observer. Whether there is an observer or not, this process happens of itself, like the radioactive decay processes which happened on the planet before man came into existence.

5. Choice in Quantum Mechanics

Classical physics theory, which includes nature and living things, has its roots in Newton's *Principia Mathematica* of 1687. Later, it was taken a step further by James Maxwell and Albert Einstein. Newton founded his work on that of Johannes Kepler. Kepler asserted that the planets move according to simple mathematical laws and that their movements were determined by their interactions with other objects. These movements were independent of human observers, and the viewpoint of classical physics was deterministic. Thus a state at any particular time could be determined by any previous state, and can predict any future state. By the use of Newtonian physics, we can calculate to the hour the orbits of the planets, the phases of the Moon, the positions of the stars in the sky by day and by season, and the distances by which asteroids will graze the Earth.

Basically it is valid for all of us that we have a life line which we cannot change by choice. Our place of birth, our father and mother, our time of birth. These are not primarily a result of our own choices, but willingly or unwillingly are affected by our parents' volition. Even so, deterministic universal rules can to a large extent be guessed (Stengers and Prigogine, 1997). This is a reflection of Newtonian physics. In Newtonian physics, if we define the state of any particular moment, we can calculate any later state just as much as any pervious state. In quantum physics however, the state of a microuniversal object is defined by $\psi(x, t)$. x and t are variables. Knowing the condition of a dynamic system in state U means knowing the numerical values taken from physical quantities. The numerical values which will be obtained at any later time can only be guessed.

Quantum mechanics has been criticized by some for involving free will. According to them, the mind's choice among various alternatives is not based on any outside objective evidence. More, it is an inference arising from our own internal subjective experience. However, according to Bohr, one of the pioneers of QM, in the long run physics will find a physical equivalent for our experiences. And mathematical equations will be developed to help to calculate and predict certain types of experiences. However, the mathematical equations of what are still rules of calculation are based on physical similarity. And for our behaviour and endogeneity, time is needed. There is a wide gap between the subjective experience in our brains and the objective experiences of the material world.

David Bohm (1952) regarded a quantum system as 'particle-like' and 'wave-like' structures complementing each other. But this view causes confusion: when a particle passes through any small space it spreads like a wave, as in the interference experiment. This dualistic state is like the mind-matter dualism. From Bohm's viewpoint comes the idea of wave function branches. For example, if a wave source is set up, it will spread from the discharge channels like light. However, this surface is only two-dimensional. A wave in QM is not two-dimensional but multi-dimensional, and for N particles, the same propagation occurs in three-dimensional space. In this case, when a measurement is made in each discharge channel, a part of the wave formed in the middle of the pool will be described. In this way, all waves will represent only one possibility for the expression of an experiment.

Bohm makes a demonstration of this by imagining a surfer in three-dimensional space. A three-dimensional wave moves in a certain direction. If the surfer is in a position to choose an exit from the pool, his choices are clear and he will enter one or the other. After the choice, any branch will result in a potential experience. With this viewpoint, Bohm's deterministic model enables us to make a statistical guess about what we will choose and what we experience. However, the branches which the surfer does not choose or does not enter have absolutely no effect on the classical world. Consciousness plays no causal role in this choice. Even though the wave at the middle of the pool at the beginning constitutes all possible experiences, the surfer chooses one of them and the experience of choice occurs. Even though Bohm's view is very practical, it brings many problems with it. First, many empty branches form. When the surfer chooses one of them, this makes all other alternative experiences unrelated. The empty branches continue forever and none of them has an effect on experience (Figure 5).

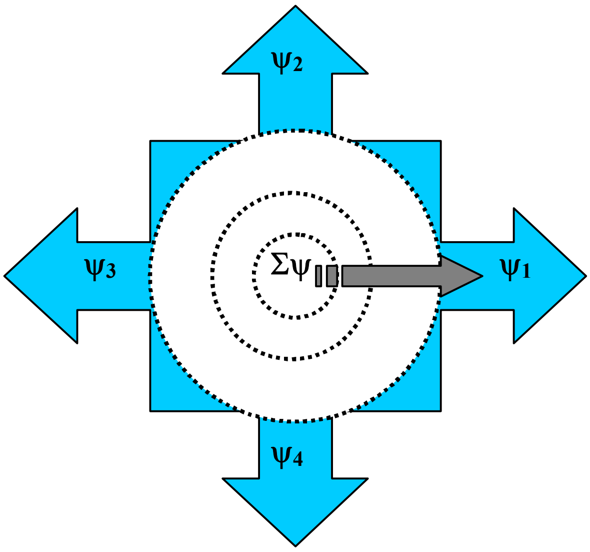

Figure 5. The separation into waves of all of the experience (Σψ) at the centre of the pool in a two-dimensional pool, ψ_1,ψ_2, ψ_3, ψ_4. The surfer can choose one of these.

Werner Heisenberg's theory (1958), unlike Bohm's, does not have a lot of empty branches. It includes realities formed from two ideas. The two parts of the idea are 'real events' and 'objective inclinations for the expression of events'. Objective inclinations can be represented by waves in a three-dimensional pool. Real events correspond to instantaneous or fast changes in this wave. Each instantaneous change forms a wave collapse in each of its waves. In this way, Bohm's surfer chooses one of the waves and this choice gives rise to the real event. Even though Bohm's surfer cannot have an effect going back in time, Heisenberg's real events prevent all but one. The only problem is the inadequacy of the explanation of how these real events arose.

According to both Eugene Wigner and Von Neumann, selection events happen when consciousness becomes involved. A physical brain event, that is wave function collapse and experience in the brain, are parallel to each other. For example, by turning the intention to raise your arm into reality as a psychological experience, the inclination to raise your arm results. To put it another way, psychologically intending to do *x* by free will is equal physically to the inclination to do *x*. Here the experimental measurement apparatus is consciousness.

Hugh Everett's view is very different from that of the others. There is no question of collapse of wave function. The universe divides into branches at the time of choices and all the branches continue to exist. Because the branches continue, the consciousness state related to 'content' in each branch also continues. Each branch exists in three-dimensional space independently of each of the others. Each branch also has its own physical memory structure, and does not interact with brain activity in other branches. Therefore each different branch can be thought of as a separate self or soul. One has no awareness of the others. At each choice which free will encounters, each of these personalities is branching and dividing again and again.

6. Is Quantum Mechanics a Completed and Correct Theory?

There are natural events which cannot be explained by the theories which began with Kepler's classical physics, continued with classical statistical mechanics and reached their final form with Maxwell's equations and classical electromagnetic theory; but they can be explained by QM. Not stopping there, it has been the harbinger and source of a good many new developments. QM has been proved a 'correct' theory by later experiments and observations. In addition to its being correct, it is a theory with internal consistency. That is, it is not possible to make two propositions from this theory which contradicts each other.

It was asserted in 1935 by Einstein-Podolsky-Rosen (EPR) that quantum theory was deficient and lacked internal consistency. In an article entitled *"Can It be Accepted that the Quantum Mechanical Description of Nature is Incomplete?"*, they reached the conclusion that the ψ-function which describes the wave function of a microuniversal object was not a complete description. In order to know whether any theory in physics which describes objective physical reality is correct or complete, it is necessary to understand two statements. For a theory to be correct, results given by the theory must coincide with experimental results. EPR accepted that that according to this criterion QM was correct. For a theory to be accepted as complete, each element of objective reality which is described must be mentioned in the theory, and each element of physical reality must have its equivalent in the theory. It must also be able to explain clearly what are the elements of objective physical reality. When this is done, it is possible to decide whether a theory which describes reality is complete or not. EPR concentrate on the definition of incompleteness and reach the judgment that it is incomplete. This is because there is no compulsion for a correct theory to be at the same time complete.

This example may illuminate incompleteness: think of a particle described by a ψ-function. If the momentum and location (P_o) of the particle are shown precisely, it will not be possible to determine where the particle is in terms of location, nor to predict the value of the spatial coordinate (x). The possibility of it being in any place are equal. If its spatial location is measured precisely, information on its momentum value will not coincide with any actually existing momentum value. If the momentum value is known precisely, the result is that the spatial coordinates for the same state will not be physically real. When precise information is obtained on one, the ψ-function does not give a complete description of physical reality because information on the other one is not available. Seeing this deficiency in QM means bringing it into the state of a complete theory by bringing in certain new variables.

7. What Does the Future Hold?

When the descriptions of what constitutes reality get more and more complex, you start to doubt your own reality. Pinching yourself to be aware of reality, you want to reach the conclusion that *'I am real'*. But QM is real. There is no doubt that it is based on solid foundations. One day a better viewpoint, but one still derived from today's basic structure of QM, will take the place of probability. This will be less controversial and will reach more certain interpretations. However, it will not reject what we know about the physical world. The change will be like that from Newtonian mechanics to Einstein's relativity. Einstein did not reject Newton's mechanics but developed and widened it.

We may think we have found a solution, but some small but important point which we hadn't thought of or hadn't seen before might affect our previous ideas and cause us to re-evaluate from the beginning. New philosophy brings concepts and therefore new problems along with it. However, a correct approach is to regard a well-asked and well-presented question as a problem solved.

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