The Action of Consciousness and the Uncertainty Principle

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Abstract: The term *action of consciousness* is used to refer to an influence, such as psychokinesis or free will, that produces an effect on matter that is correlated to mental intention, but not completely determined by physical conditions. Such an action could not conserve energy. But in that case, one wonders why, when highly accurate measurements are done, occasions of non-conserved energy (generated perhaps by unconscious PK) are not detected. A possible explanation is that actions of consciousness take place within the limits of the uncertainty principle. Two models are reviewed that, using the latter assumption, propose that consciousness can originate an action potential in the brain. One (that of Eccles) uses the latter assumption only, and the other (that of Burns) additionally assumes that consciousness acts, within those limits, by ordering quantum fluctuations.

We will use the term *action of consciousness* to refer to an influence, such as psychokinesis (PK) or free will, that produces an effect on matter that is correlated to mental intention, with the effect not completely determined by physical conditions. It is not known whether free will exists. But there is a great deal of laboratory evidence that establishes the existence of PK (see, e.g., Jahn et al. (1997)). However, little is known about how such an influence produces an effect, except that it cannot be by any known physical means (Burns, 2003). (It cannot work by quantum nonlocality, as presently understood in physics, because quantum nonlocality links systems by correlations only and does not permit the transfer of a signal or any means of generating a force.)

Indeed, the reason that many people question whether PK exists is that if it does, it could not affect matter in the same way as known physical forces. On the other hand, PK and other psi-based effects all differ from solely physical interactions because they involve consciousness. So one could conclude that the nature of such interactions is different from the solely physical interactions that presently known physics describes.

In that case the difference between the two types of interactions is apt to be substantial, and one major difference would be in the role energy plays in the different types. As is well known, energy is conserved in solely physical interactions. On the other hand, because energy is conserved in such interactions, it follows that energy cannot be conserved when effects on matter are produced in a non-physical way (Burns, 2006).

However, although PK effects in the laboratory are produced with conscious intent, such effects are also known to occur with unconscious intention. So if inadvertent PK effects occurred in ordinary physics or engineering work, the deficit (or excess) of energy with respect to what would be expected for a solely physical interaction could be measured. With sufficiently accurate instruments, it could be measured all the way down to the limits allowed by the uncertainty principle for the interaction involved. But such effects are not reported. One possible explanation is that the physical changes produced by PK can be no more than what is allowed by the limits of the uncertainty principle.

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Various proposals have been made that the action of consciousness on matter (i.e., free will and/or PK) takes place within the limits of the uncertainty principle. However, beyond the simple assumption that the action of consciousness occurs only within those limits, the framework of the model can vary. The rest of this paper primarily describes my own model (Burns, 2002a; 2006). However, the proposal by Eccles (1970) makes a good starting point in the discussion of this type of model, as it makes the above assumption about the action of consciousness occurring within the limits of the uncertainty principle and adds no other framework. On the other hand my model adds another feature, namely that consciousness acts by ordering quantum fluctuations that would ordinarily be random. As we will see, this addition leads to predictions that would not be made using solely the former simple model.

Now let's go to the basic assumption that consciousness can produce physical changes within the limits of the uncertainty principle. This assumption can be stated in a little more detail as follows. The physical object to be affected has spatial coordinates x, momentum coordinates p_x, and energy E. According to the uncertainty principle, there are uncertainties in the measurements of these coordinates, which we label as δx, δp_x, and δE, and the product of certain pairs of these uncertainties cannot be less than $\hbar/2$,[1] where $\hbar$ equals Planck's constant divided by 2π. Specifically, $\delta x \delta p_x \geq \hbar/2$ and $\delta E \delta t \geq \hbar/2$, where t is the elapsed time involved. So if it is assumed that the minimum uncertainty in measurement in each coordinate specifies the maximum shift that the coordinate can make because of the influence of consciousness, then the products of shifts in certain pairs of coordinates cannot exceed $\hbar/2$.

Eccles (1970) has used the above basic assumption in his model of the action of consciousness on matter. Specifically, he has noted that in ordinary brain processes an action potential can be generated through the change in position of vesicles at a synapse. So he has proposed that consciousness could generate an action potential by making such shifts in position. However, Wilson (1999) has shown that in moving a vesicle, the energy and time elapsed are such that the product exceeds the maximum value allowed by the uncertainty principle. So consciousness could not produce an action potential in this way. In fact, Wilson has examined a variety of ways in which an action potential

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[1] The term $\hbar/2$ is used, rather than $\hbar$, because we are referring to root mean square values of the changes in each coordinate, not to single instances of change.

could be produced and has shown that none of them can be done within the limits of the uncertainty principle.

The reason that such effects can't be produced at the cellular level is basically that coordinates such as δp_x and δE are proportional to the mass of the object to be affected. But the products involving these coordinates must be less than $\hbar/2$, which is a very small number. So objects at the cellular level, such as a vesicle, are just too massive to have products of changes concerning them fit within the limits of the uncertainty principle. We will see a little later that if changes within the limits of the uncertainty principle are made at the molecular level, an action potential can be generated by such changes, but we need to cover some further basic material first.

The Cumulative Effect of Quantum Fluctuations

According to quantum mechanics, any object is subject to a continuing series of fluctuations in its energy and its spatial and momentum coordinates. These fluctuations occur within the limits of the uncertainty principle and are called *quantum fluctuations*. Also, in each region of space there arise particles for which the product of their lifetime δt and energy δE is about equal to $\hbar/2$. These particles are referred to as *vacuum radiation*. (Under ordinary conditions of temperature and pressure these particles are primarily photons.) Quantum fluctuations in objects are commonly considered to be caused by the interaction of vacuum radiation with those objects.

The quantum fluctuations of an object are random. However, I am going to propose in my model that the action of consciousness produces its physical effects through the ordering of randomness in these fluctuations. First though, we need to know a little more about ordinary random fluctuations, specifically the root mean square magnitudes of the fluctuations in the individual coordinates of the objects affected and the cumulative effect of these fluctuations over time. So we will take up that subject next.

To obtain the root mean square values of the fluctuations, we start with an expression called the *action integral*. This expression describes the trajectory of an object from one position in space and time to another, as determined by the dynamical forces acting on it, but not including any stochastic effects, such as those from quantum fluctuations. Now if an object is following a dynamical trajectory with certain initial conditions, and a non-dynamical change is made such that the object now follows a neighboring dynamical trajectory that has different initial conditions, the values of the action integral for the two cases will be different. Let us assume that when a coordinate makes a non-dynamical change with magnitude equal to the root mean square magnitude of its fluctuation, the change thereby produced in the value of the action integral is the same, regardless of which coordinate produces the change.

To simplify the analysis we additionally assume we have a system of freely traveling particles that only interact when they are very close. (The molecules of most liquids and gases at ordinary temperatures and pressures satisfy this condition.) Analysis tells us that the root mean square magnitude of the fluctuation for any given particle is $\delta x =$

$(\hbar/m)^{1/2} t^{1/2}$; $\delta t = (\hbar/2E)^{1/2} t^{1/2}$; $\delta p_x/p = 1/2 (\hbar/2E)^{1/2} t^{-1/2}$; $\delta E/E = (\hbar/2E)^{1/2} t^{-1/2}$, where m is the mass of the particle and p the magnitude of the momentum (Burns, 1998, 2010).

An important result is the time dependence of these quantities. The fractional change in momentum $\delta p_x/p$ and the fractional change in energy $\delta E/E$ both depend on $t^{-1/2}$ so they get smaller as time increases. In other words, even though energy and momentum are subject to fluctuations, they tend to be conserved as time increases. On the other hand, δx and δt are both proportional to $t^{1/2}$, a time dependence which is characteristic of diffusion. So although a particle starts its dynamical trajectory, as determined by the action integral, from some particular initial position and time, the effect of the stochastic perturbations is that the particle drifts to neighboring dynamical trajectories, corresponding to different initial positions and times, rather than staying on its original trajectory.

To see another important result let's ask what happens when the freely traveling molecules come near to each other and interact. We will use air at standard conditions as an example. The collision time (the time a particle travels between interactions) is 1.55 x 10^{-9} seconds , and over that time the fractional change in momentum $\delta p_x/p$ equals 1.17 x 10^{-3}. Therefore, as we noted, momentum tends to be conserved. However, in the interaction, the change in momentum is amplified by a factor $A = \lambda/r$, where λ is the mean free path[2] and r is the radius corresponding to the value of the interaction cross section. Furthermore, if the fractional change is greater than 2, the original direction of the momentum can be changed to any other direction. So if the fractional change becomes that large after an interaction, the momentum of the molecules will become completely redistributed between them. It can be readily computed that for air $A = 8.06$ x 10^3, and $(\delta p_x/p)A = 9.43$. So momentum is completely redistributed in one collision time. Furthermore, the original shifts were random, so the redistribution is also a randomization (Burns, 2007).

In the above example we have seen that in a system of traveling particles, quantum fluctuations not only produce shifts in the coordinates of the particles, but also have the effect, when the molecules interact, of randomizing the momentum in the system. Let us inquire as to the general range of conditions in which this randomization can occur.

Let us first note that in each successive interaction the magnifying factor A is applied again, so systems that don't completely randomize in one collision time may do so in a few collision times. Analysis for liquids and gases shows that complete randomization can occur over a very broad range of temperatures and pressures in a few collision times. No analysis has been done for solids. However, because molecules in solids interact with their neighbors, it is plausible that a similar effect can take place in these (Burns, 2007).

When an isolated system is completely randomized, all microstates are equally possible. In that case the system is in equilibrium and in a state of maximum entropy (Huang, 1987). So it appears plausible, according to the analysis given here, that the effect of quantum fluctuations, or equivalently vacuum radiation, on an isolated system is to take it

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[2] The mean free path is the average distance a particle travels between interactions.

into the state of maximum entropy. If this is the case, vacuum radiation is responsible for the second law of thermodynamics.

The Action of Consciousness and the Ordering of Randomness

Let us now assume that consciousness acts on an object by ordering random shifts in its spatial or momentum coordinates that are produced by quantum fluctuations (or equivalently vacuum radiation), such that the direction of the shift is not random, but in a preferred direction. As we have seen, the magnitude of these fluctuations is very small. However, we have also seen that at least in liquids and gases, the effects of these shifts can be greatly magnified by interactions with other particles, to the extent that the original direction of travel can be changed to any other direction in one, or a few, collision times. Without the influence of consciousness, the changes in direction are random. But with the influence of consciousness the direction of a traveling molecule can be changed (after interaction) to any preferred direction. So by means of this magnification a fairly substantial effect can be produced.

The amount of non-conserved energy involved is very small. In the first part of its path, before interaction, a molecule would have a small surplus or deficit of energy δE, which would be borrowed from or by the vacuum. (δE is a root mean square, and individual fluctuations can be either positive or negative.) Using our previous example of air at ordinary temperatures and pressures $\delta E/E = 2\delta p_x/p \sim 2 \times 10^{-3}$, so only a small fraction of the molecule's energy is involved. The magnification itself does not take any energy to or from the vacuum. Furthermore, if a randomly chosen group of molecules were ordered, some molecules would have a deficit to the vacuum, and others would have a surplus. The net result would be that if n molecules were ordered, the average deficit would be zero, and variations around that would be proportional to $n^{1/2}$, not n. So the amount of non-conserved energy (the amount borrowed from or by the vacuum) is very small.

Once the molecules have interacted and are ordered, their energy, which was previously disordered, would be converted to ordered energy, which can do work. So their energy is conserved – it is simply converted from one type to another. However, the conversion contradicts the second law of thermodynamics, which says that disordered energy cannot be converted to energy that can do work, with no other effect. Or looked at another way, rather than a contradiction, the possibility of this sort of process could be viewed as an extension of the second law, that describes the action of consciousness on matter.

As an example of a process in which the ordering by consciousness of a group of molecules could produce an observable effect, let's consider the production of an action potential in the brain. In order for an action potential to occur, sodium channels must be opened in the neuronal membrane. A sodium channel is held closed by a gate formed by a protein molecule in the membrane, and the gate is opened when chemical bonds are broken, and the molecule changes its conformation (Wilson, 1999).

Usually the gates are opened in an electrochemical process. However, the neuron is immersed in the intercellular medium, which is largely composed of water. So let's

suppose that a group of water molecules are ordered and break the chemical bonds by their impact. Let's ask how many ordered water molecules, traveling at thermal velocity, it would take to break a bond, open a gate, and produce an action potential, respectively.

We take $E_M = 5.0 \times 10^{-19}$ joule as the average amount of energy to break an ionic or covalent bond, and let n be the number of ordered water molecules needed to break it. We suppose the water molecules have mass m, that the gate has a mass M, and estimate that $M/m = 100$. We also suppose that upon impact, energy from the water molecules transfers elastically to the gate and that this energy then dissipates into the gate and breaks the bond. Using conservation of energy and momentum, it can then be found that n is about equal to 80 (Burns, 2002a).

Let us estimate that 5 bonds need to be broken to open a gate. We then have 5 groups of traveling molecules, impacting at slightly different places, for a total of 400 molecules. We note that each molecule must have its ordering interaction within a mean free path of its destination, the reason being that otherwise its velocity will be randomized in the succeeding interaction. So each ordered group will exist as an ordered group only for that distance.

It is usually necessary to open more than one gate to produce an action potential. Let us estimate that 5 gates are opened. This then brings us to 2,000 ordered molecules to produce an action potential.

We should note that for each molecule that is ordered, another molecule – the one it interacts with – must also be influenced, in order for it to be in the right position to do the ordering. So the total number of molecules influenced is twice the number that are ordered. In the above case, the total number of molecules influenced to initiate an action potential is 2(2,000) = 4,000.

The size of an effect that consciousness can produce would evidently be limited by the number of independent particles that it can order at one time. In this regard we should note that because consciousness is ordering a particle that is subject to constant fluctuations, it must exert its influence during the entire time the particle is traversing the mean free path before interaction, in order to be able to affect all the shifts that can affect the ordering.

Given this limitation, it would be of interest to compare the number of ordered particles needed to produce various types of PK effects. It would seem that for ordinary people producing PK in laboratory experiments under ordinary circumstances, the number of orderings required to produce the PK effects obtained in different experiments would be similar, regardless of the type of experiment. (The number required for macro PK would doubtless be much higher, but macro PK seems to need special circumstances.)

Also, the number of orderings needed to produce laboratory PK results could be compared to the number estimated to be used by the brain. We have seen that the number needed to produce an action potential in the brain is 2,000. However, assuming consciousness produces more than one action potential at a time, and perhaps other sorts

of physical effects also, the upper limit could be several orders of magnitude higher. So it is of interest that the PK deviation of a traveling cube, measured in laboratory experiments, can be explained by the impact of 2×10^5 ordered air molecules on it at the beginning of its trajectory (Burns, 2002b).

Summary of Conclusions

* If consciousness can produce a physical effect that is not completely determined by physical conditions, energy cannot be conserved in the interaction.

* In order for such an effect to be compatible with physical laws, one solution could be that interactions between consciousness and the physical world must take place within the limits of the uncertainty principle. In this formulation the product of certain pairs of coordinates, such as energy and time elapsed, cannot exceed $\hbar/2$.

* Two basic types of model have been used to explore the above idea. One, the simpler one, allows the values of individual coordinates in the pairs to be chosen arbitrarily, provided only that the product does not exceed $\hbar/2$. This type of model was used by Eccles (1970) and applied to the generation of an action potential at a synapse. However, it has been shown that the product of energy and time that describes such a process is greater than $\hbar/2$. Therefore, this type of model cannot be applied to objects at the cellular level – they are too massive for processes involving them to fit within the uncertainty constraints.

* The other type of model (the one I use) notes that ongoing processes already occur within the limits of the uncertainty principle – these are the random fluctuations in energy and spatial and momentum coordinates that all objects undergo, and they are called *quantum fluctuations*. In this type of model it is assumed that consciousness can interact with matter through the ordering of these fluctuations, i.e., instead of being random, the coordinate shifts occur in a preferred direction.

* By making a simple assumption in order to obtain values of the root mean square shifts in individual coordinates, it is shown that cumulative shifts in energy and momentum coordinates are proportional to $t^{-1/2}$, where t is time. Therefore, even though these coordinates fluctuate, energy and momentum tend to be conserved over time.

* It is shown that in liquids and gases, in which molecules spend most of their time traveling freely and only interact at the end of a mean free path, the small net shifts in momentum components are greatly magnified by the interaction at the end of the path, such that the magnified shifts can change a molecule from traveling in its original direction to any other direction in one, or a few, mean free paths. Because the shifts are random, the new directions are random, and in this way the distribution of momenta becomes randomized.

* If consciousness can order the above process, i.e., change the original direction of molecules to new preferred directions, it can also change a group of molecules traveling in random directions to a group all traveling in the same direction. In that

case the action of consciousness turns heat (disordered energy) into work (ordered energy), with no other effect. This latter process can be viewed as contrary to the second law of thermodynamics. Alternatively, it can be viewed as an extension to the second law that describes the interaction of consciousness with matter.

* The above ordering process can be used to produce an action potential in the brain. To initiate one, sodium channels must open in the neural membrane, and this is usually done in an electrochemical process. However, the gates to the channels use chemical bonds to hold them closed. So to open the channels it is presumably only necessary to impact the bonds with streams of molecules and break them. The streams of molecules can be obtained by the ordering of water molecules in the intercellular medium. Calculation shows that it takes about 80 ordered water molecules, moving at thermal velocity, to break one chemical bond, and about 2,000 to produce an action potential. There is no expenditure of energy – the ordered water molecules retain their original magnitude of velocity (thermal); they previously traveled in random directions and now are directed toward a gate in the neural membrane.

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