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The Arrow of Time and the Action of the Mind at the Molecular Level

Jean E. Burns*

**1525 153rd Ave., San Leandro, CA 94578, USA; Email:* jeanbur@earthlink.net

Abstract. A *new event* is defined as an intervention in the time reversible dynamical trajectories of particles in a system. New events are then assumed to be quantum fluctuations in the spatial and momentum coordinates, and mental action is assumed to work by ordering such fluctuations. It is shown that when the cumulative values of such fluctuations in a mean free path of a molecule are magnified by molecular interaction at the end of that path, the momentum of a molecule can be changed from its original direction to any other direction. In this way mental action can produce effects through the ordering of thermal motions. Examples are given which show that the ordering of 10^4-10^5 molecules is sufficient to (a) produce detectible PK results and (b) open sufficient ion channels in the brain to initiate a physical action.

The relationship of the above model to the arrow of time is discussed.

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INTRODUCTION

This paper will contrast events which are described by the dynamical laws of physics with what we will call *new events*, which are not predicted by those laws. The latter events could be random, free will or psychokinesis (PK).

We will first examine some basic differences between events predicted by dynamical laws and new events. We will then consider in greater detail new events which consist of shifts in the spatial and momentum coordinates of particles, with the magnitude of such shifts occurring within the limits of the uncertainty principle. We will first consider coordinate shifts which are random. We will see that the cumulative effect of such shifts over one mean free path, when magnified by molecular interaction, is to randomize the momentum distribution of particles. We will next examine the effect of ordered shifts and will see that these can order the motions of molecules in one mean free path. We will also see that the impact of ordered molecules can produce an action potential in the brain and, outside the body, detectible PK effects.

The new events, because they are not predicted by dynamical laws, yet affect future events, are associated with an arrow of time. We will investigate the nature of this arrow of time.

DYNAMICALLY-PREDICTED EVENTS AND NEW EVENTS

The dynamical laws of physics are time reversible. They describe the change of a system in time – in classical physics they describe the motion of its component parts and in quantum mechanics they describe the evolution of the wave function. And because they are time reversible, for any change of the system described by these laws with time *t* moving in the forward direction, the change when -*t* is substituted for *t* can also occur in nature [1]. On the other hand, once the complete motion or evolution, as determined at any arbitrary starting time, is specified, there can be no change in this evolution at some later time; otherwise it would not be time reversible. Similarly, Wheeler-Feynman showed that an electromagnetic wave can be viewed as having components traveling forward in time (moving away from the source) and components traveling backward in time (moving toward the source). But their proof of this equivalence depended on the time reversibility of the wave motion [2].

Let us now suppose that in a system described by a set of dynamical laws a new event, not predicted by those laws, occurs at a certain time *t*. We will suppose that this new event could be either a random event, a free will choice, or PK. (By random here is meant truly physically random, i.e., a quantum mechanical event.) But in any case the new event was not determined by any dynamical laws, not those for the system or even those governing distant events that might cause a new local influence to appear in the system.

The evolution of the system was previously set by initial conditions, which could be set at any time, past or future, because the dynamical laws are time reversible. The only way a new event, not encompassed by the dynamical laws which apply to all previous events, near and distant, could affect the system is that at least some particles in it must shift their dynamical evolution, i.e., the initial conditions which determine the specific evolution must change. In quantum mechanics this change could be associated with collapse of the wave function, which is basically a change in initial conditions, or more generally with a change in probability amplitudes. Or if the change is described in terms of classical physics, there will be a shift in initial conditions of the trajectories of the particles. This means that the new dynamical evolution no longer accurately reflects the past history of the system.

THE EFFECT OF RANDOM FLUCTUATIONS ON MATTER

Let us now apply these concepts to the molecular level. We will use a semi-classical approach, in which molecules have trajectories specified in terms of a set of spatial coordinates *x* and momentum coordinates p_x. Let us suppose that the new events are random and that they consist of shifts in spatial and momentum coordinates, with the product of the root mean square values of these shifts, $<dx^2>^{1/2}$ and $<dp_x{}^2>^{1/2}$, respectively, being specified by the limits of the uncertainty principle,

$$<dx^2>^{1/2}<dp_x{}^2>^{1/2}=\hbar/2 \qquad (1)$$

In other words these random new events are quantum fluctuations in the particle coordinates. We should note that these fluctuations can be thought of as being produced by vacuum radiation [3]. We will discuss this point at more length in the section on the "Arrow of Time."

The trajectory of each molecule is specified by initial conditions x_0 and $p_{x,0}$ at a time t_0, and the effect of quantum fluctuations is to change the initial conditions. Because the fluctuations are random in each coordinate, the changes in initial conditions of individual molecules will vary. The uncertainty principle specifies the product of the root mean square averages $<dx^2>^{1/2}$ and $<dp_x{}^2>^{1/2}$, but not the individual values. We will specify the latter by assuming that the root mean square changes are such that the change in action A for these is the same regardless of which coordinate is changed.

The result for a free particle is [3]

$$<dx^2>^{1/2} = \left[\frac{\hbar t}{m}\right]^{1/2}, \tag{2}$$

where $\hbar$ is Planck's constant and m is the mass of the particle. The $t^{1/2}$ dependence of $<dx^2>^{1/2}$ is characteristic of Brownian motion and means that each molecule will do a random walk about its original trajectory.

The root mean square value for the momentum components can be obtained from the uncertainty principle (equation (1)). Dividing by p, the magnitude of the total momentum, we find [3]

$$\frac{<dp_x{}^2>^{1/2}}{p} = \frac{1}{2^{3/2}}\left[\frac{\hbar}{Et}\right]^{1/2}, \tag{3}$$

where E is the energy of the particle. The above method also gives the fractional change in energy [3]

$$\frac{<dE^2>^{1/2}}{E} = \frac{1}{2^{1/2}}\left[\frac{\hbar}{Et}\right]^{1/2} \tag{4}$$

We note that dp_x/p and dE/E are proportional to $t^{-1/2}$, so energy and momentum tend to be conserved as t becomes large [3].

A calculation by Rueda [4,5] provides another way to estimate the effect of quantum fluctuations on matter. As we noted earlier, quantum fluctuations are considered to be produced by the action of vacuum radiation, and Rueda made a semi-classical calculation of the effect of vacuum radiation on a particle, using its known frequency spectrum. His calculation showed that vacuum radiation produces a Brownian motion, with diffusion constant $D = \hbar/2m$. The magnitude of spatial drift in diffusive motion is $<dx^2>^{1/2} = (2Dt)^{1/2}$. So $<dx^2>^{1/2} = (\hbar t/m)^{1/2}$, in agreement with equation (2).

Another method of estimating this effect is through the stochastic interpretation of the Schroedinger equation. In this interpretation the resemblance of the latter equation to the diffusion equation is noted, and a diffusion constant can be calculated to be $\hbar/2m$ [6,7]. This yields the same value for $<dx^2>^{1/2}$ as above.

The coordinate shifts due to quantum fluctuations are small. But in each molecular interaction these shifts are magnified. It can be shown that $<dp_x^2>^{1/2}/p \geq 2$ after the cumulative shift over a mean free path is magnified by molecular interaction, with this relationship holding over a broad range of temperature and pressure, including standard conditions [3]. This means that after molecular interaction a molecule can be shifted from its original direction to any other direction. We have seen that total momentum is conserved, on the average. However, the effects of quantum fluctuations are random, so the new momentum components are in the most probable state. Therefore, quantum fluctuations, when their effects are magnified by molecular interactions, can account for entropy increase in thermodynamic systems [3].

SPECIAL CONSIDERATIONS REGARDING MENTAL ACTION

In the next section we will examine the effects of ordering quantum fluctuations. Before doing that, however, we need to take into account some special considerations that apply to mental action. First, we will see that on the basis of evidence in neurophysiology, free will must be considered a process that selects among and initiates programs generated by the brain. It follows from this that the action of free will on matter is simply to initiate a brain program. Second, we will review Mohrhoff's [8] finding of the characteristic mental action must have in order that it need not conserve energy.

With regard to the first topic, it is not known experimentally whether free will exists. However, it is known through the study of brain potentials that if free will does exist, it must act as a selection process. In brief, in experiments of Libet and co-workers [9] subjects were instructed to carry out a physical action at a time of their own choosing, and the time of their intention was recorded. Brain potentials showed that brain centers associated with the muscles to carry out the action were activated *before* the conscious intention to carry it out, although the action itself was carried out after the intention. So free will in this instance could have been at most initiating or veto power, to perform the action or not.

It is a common experience to hold several possibilities in mind at once and then decide to carry out one of them. So it is assumed herein that free will can also select among several possibilities. However, to be consistent with the above, choices can only be made among possibilities the brain has presented.

We conclude that free will does not itself generate the choices which are presented to conscious thought, but can select among alternatives generated by the brain and can initiate a brain program. Therefore, in explaining the action of free will on matter, it is only necessary to explain how a brain program already present is initiated.

With regard to the second topic, the action of free will would involve physical changes in the brain that would not be determined by physical laws. Therefore, it would not conserve energy [10], and it is often thought that free will cannot exist for that reason. However, Mohrhoff [8] showed that the principle of energy conservation only applies to mathematically determined changes. So if the action of free will is free, and not mathematically determined, there is no need for energy conservation.

Of course, we expect the energy involved in any free will action to be small. Otherwise, it would be noticeable in experiments involving the brain. However, as noted above, we are considering the physical effects of free will and PK to be produced through the ordering of quantum fluctuations, and these fluctuations take place within the limits of the uncertainty principle. We will see in the next section that the energy involved is very small.

To sum up the latter topic, in order for free will not to be subject to energy conservation (which it cannot satisfy), its action must be in some way arbitrary – it cannot be entirely determined by physical conditions, in the brain or otherwise. We will assume that a person's conscious intention to do PK also has an arbitrary element, in that he or she can either hold the intention or not.

ORDERING QUANTUM FLUCTUATIONS BY THE ACTION OF THE MIND

Let us now assume that mental action takes place by the ordering of quantum fluctuations in spatial and momentum coordinates of molecules (or equivalently, by the ordering of the vacuum radiation that produces these fluctuations). We will assume that ordering can take place in either spatial or momentum coordinates, with the root mean square values of the cumulative fluctuations being given by equations (2) and (3). The ordering itself takes place within the limits of the uncertainty principle and so can never be detected. However, after the affected molecule travels one mean free path, the cumulative effect of the fluctuations is magnified by the molecular interaction at the end of that distance. It is this magnification that allows detectible events to take place.

At standard conditions either a spatial shift or a momentum shift can, after magnification through molecular interaction, produce a change from a molecule's original direction to any other direction [11]. However, we will use a shift in momentum coordinates in all our examples. Let us first examine how free will could work.

Producing an Action Potential in the Brain

Wilson [12] has discussed the necessary conditions for mental influence to produce an action potential in the brain. An action potential occurs when sodium channels are opened in the neuronal membrane. These channels are usually held closed by a gate formed by the arm of a protein molecule in the membrane. The gate is opened when chemical bonds are broken, and the molecule changes its conformation. The energy of a typical ionic or covalent bond is about 5.0×10^{-19} J [12].

Let us suppose that water molecules (or any light molecules) in the intercellular medium have their direction ordered to strike the gate head on. We suppose the gate has a mass M, and n lighter molecules of mass m are ordered. The velocities of the lighter molecules before and after impact are v and v', respectively. Before impact the velocity of M is zero, and after impact it is V. By conservation of energy and momentum

$$\frac{nmv^2}{2} = \frac{nm(v')^2}{2} + \frac{MV^2}{2} \tag{5}$$

$$nmv = nmv' + MV \tag{6}$$

Let $E_M = MV^2/2$, the energy imparted to the arm after impact. With a little algebra we find

$$E_M = 4n^2 \frac{mv^2}{2}\frac{m}{M}\frac{1}{(1+nm/M)^2} \tag{7}$$

The small molecules have thermal energy, so we write $E_{th} = mv^2/2$. Solving for n, we find

$$n = \frac{(E_M/4E_{th})^{1/2}(M/m)^{1/2}}{1-(E_M/4E_{th})^{1/2}(m/M)^{1/2}} \tag{8}$$

$E_M = 5.0\times10^{-19}$ J, the amount to break a chemical bond, and $E_{th} = 3/2kT$, where T is the temperature and k is Boltzmann's constant. We set T = 298 K and find $E_{th} = 6.17\times10^{-21}$ J. If M/m = 100, n = 81.8 molecules. In round numbers, about 80 molecules must be ordered to provide sufficient energy to break an ionic or covalent bond.

If 5 bonds must be broken, it would take 400 ordered molecules to open the gate. It is usually necessary to open more than one gate to produce an action potential [12]. Furthermore, initiating a physical action probably takes more than one action potential although the number needed is not presently known [12]. If we multiply by 10 to estimate the latter factors, we find that about 4,000 molecules must be ordered to initiate a physical action.

The Pressure Produced by Ordered Molecules

We are assuming that mental influence can act outside the brain to produce PK, as well as inside the brain in free will. Let us now ask the pressure which can be produced by ordering molecules in a gas. In thermal motion each component of velocity, v_x, shares equally in the energy $E = (3/2)kT$, so $v_x = (kT/m)^{1/2}$. Let n be the number of molecules per volume. Then the pressure P produced by thermal motion equals $n/2(2mv_x)v_x = nmv_x^2 = nkT$.

In ordered motion all the energy is available to the component traveling in the desired direction, so the component, v'_x, equals $(3kT/m)^{1/2}$. Let the number of ordered molecules per unit volume be n_{ord}. Then the partial pressure produced by those molecules equals $n_{ord}(2mv'_x)\,v'_x = 6n_{ord}kT$. Therefore, the excess pressure ΔP is given by

$$\Delta P = n_{ord}\left(5kT\right) \tag{9}$$

The Number of Molecules N_{infl} Which Are Simultaneously Influenced

We would like to know the number of molecules N_{infl} which must be simultaneously influenced to produce a pressure ΔP. Each molecule to be ordered has to be influenced over the entire mean free path, in order to be properly positioned for the interaction which produces the final result. Therefore, the number simultaneously ordered is $n_{ord}\, l\, A$, where l is the mean free path and A the cross section acted upon. We can evaluate n_{ord} from equation (9); l can be expressed as [13]

$$l = \frac{(2p)^{1/2}}{8}\frac{kT}{Ps}\ , \tag{10}$$

where s is the interaction cross section.

We must keep in mind that the molecules that the ordered molecules interact with at the end of a mean free path must also be influenced so they will be in the right place at the right time. Therefore, $N_{infl} = 2n_{ord}\, l\, A$. We find

$$N_{\text{infl}} = \frac{(2p)^{1/2}}{20}\frac{A}{s}\frac{\Delta P}{P} \tag{11}$$

PK effects are generally small, so there must be some limiting factor that ordinarily applies. One possibility is that a person can simultaneously influence only a certain number of molecules at a time. On the other hand, perhaps it is not the number of molecules but the rate of processing them that provides a limitation. Let us examine what is involved in these two possibilities. We will see that we can rule out one of them.

The rate of processing of the molecules is N_{infl}/t, where t is given by [13]

$$t = \frac{p^{1/2}}{8}\frac{(mkT)^{1/2}}{Ps} \tag{12}$$

Therefore, N_{infl}/t is proportional to $\Delta P/(mkT)^{1/2}$ and independent of pressure. Suppose N_{infl}/t is a constant for a given operator. Then at a given temperature, an operator could produce a constant excess pressure ΔP, independent of pressure. This would mean that if the pressure became small enough, ΔP would become comparable to P, and PK effects would be easily seen. But this doesn't happen. So we can rule out this possibility.

On the other hand, suppose N_{infl} is a constant for a given operator. Then, by equation (11), $\Delta P/P$ is constant. If a person produces a small effect $\Delta P/P$ at atmospheric pressure, he or she will produce the same fractional effect at low pressure. So if the effect is not readily observable at atmospheric pressure, it will not be evident at low pressure either.

Therefore, it is a reasonable supposition that N_{infl} has a similar value in different types of mental action and provides a physical constraint that limits the effect an operator can produce. In the example of free will, we estimated that to initiate a physical action, about $4\text{x}10^3$ molecules must be ordered. As noted above, the number to be influenced must be twice that because the interacting molecule at the end of each mean free path, which provides a magnification of the original effect, must be influenced to be in the right place. This yields about $8\text{x}10^3$ to be influenced, which we will round off to 10^4. In the rest of this section we will examine PK effects which could be produced with a similar number of molecules, to within an order of magnitude or so.

Of course, the amount of PK effect produced by a given operator also depends on psychological variables, such as mood [14], and all these taken together determine the amount of PK effect. We can reasonably account for this by supposing that N_{infl} can be enhanced, perhaps substantially, when psychological variables present favorable conditions for PK.

Detecting PK Effects with a Microphone

A microphone can detect a fluctuating pressure wave. If a PK-produced pressure wave is to be detected by a microphone, two elements are necessary: a sufficiently large amplitude ΔP and a coherent variation of ΔP in time across the macroscopic surface of the microphone. Let us first ask how many molecules must be simultaneously influenced to produce a detectible pressure amplitude.

An ordinary microphone can detect a sound level of 30 dB ($6.3\text{x}10^{-4}$ N/m^2), and a low-noise microphone can detect -2.5 dB ($1.5\text{x}10^{-5}$ N/m^2) [15]. Using equation (11) and setting $A = .10$ cm^2, we find for a low-noise microphone $N_{\text{infl}} = 9.37\text{x}10^3 \approx 10^4$ molecules [16].

The above is about the same as the number of molecules that are influenced in initiating a physical action, which suggests that it might be feasible to produce PK-induced sounds in microphones. On the other hand, in our example of opening an ion gate in the brain, no coordination of molecules was necessary. All that was needed was the impact of sufficient molecules during a collision time t to break some chemical bonds. The fact that PK effects are not commonly detected in microphones suggests that most operators cannot produce a coherent fluctuating wave. But perhaps some people could. Using a microphone for detection of PK-induced pressure waves might be a fruitful way of exploring PK.

The Tumbling Cube

Tumbling cubes (dice) have been used in games of chance for centuries, and this implies that they are subject to PK effects to some extent. Let's inquire what the above model predicts in this regard.

Dynamical analysis predicts that if a cube is given a velocity in the forward direction, its final sideways position depends on the orientation of the cube when it begins its trip [17]. So if a small change in orientation can be produced by PK during the first tumble of the cube, there will be a measurable deviation in sideways position at the end of the trajectory, with this change depending on the length of the trajectory. (This deviation must be found by averaging over a large number of trips, in order to average out the effect of random factors, such as air currents and irregularities in the surface the cube travels on [17].) Analysis shows that for the first s_0 steps (tumbles), this deviation is very small. After that, it increases linearly with the length of the trajectory [17].

E. H. Walker [18] was the first to show that a small PK-induced rotation of a cube at the beginning of its trajectory could produce a sideways deviation in the final endpoint, and he proposed that a quantum fluctuation in the orientation of the cube could account for sideways deviation in the trajectory. Walker applied his theory to an extensive set of data produced by Forwald [19] with cubes that traveled over a long trajectory, and he concluded that Forwald's results were in accord with his proposal. However, Walker had made simplifying assumptions in his dynamical analysis, and when the analysis was made in more detail, it turned out that a quantum fluctuation of an object of macroscopic mass was too small to account for Forwald's results [20]. On the other hand, it has been shown that the pressure produced by ordered molecules can account for these results [20].

As noted above, the endpoint of the cube trajectory is extremely sensitive to perturbations at the beginning of the trajectory. For that reason, cubes should be shielded against air currents – e.g., caused by breath or hand movements of a nearby person – which might be correlated with PK intention. However, Forwald was not aware of this extreme sensitivity and took no such precautions. So it is not known whether his results were due to PK or merely to air currents which were correlated with his PK intentions [17,20]. However, we can ask how much pressure and how many molecules were involved.

The answer to the above question is that a pressure of $1.5\text{x}10^{-5}$ N/m^2 was needed during the first tumble of the cube to produce the sideways deviation, correlated with intention, that Forwald found at the end of the trajectory [20]. This is the about the magnitude of a barely detectible (0 dB) sound wave (see Note [15]). To produce this pressure by PK-ordered molecules, $2\text{x}10^5$ molecules must be influenced [20]. This number is an order of magnitude larger than our estimate for the number of molecules involved in a free will action, but given that these are estimates, the difference between them is not extremely large.

The above result assumes that both the pressure and the number of molecules influenced acted on the cube for the full duration of the first tumble, which takes about 1.7×10^{-2} s [20]. (Otherwise the pressure and number of molecules would be larger.) In our estimate of the number of ordered molecules needed to open an ion gate, the energy to break the chemical bonds can be imparted in one collision time, which is about 10^{-9} s. However, the ordering action must last much longer than that because the gates must be held open in order for ions to pass through the channels, and the gates remain open for at least 10^{-5} s [12]. A series of actions might necessitate a series of action potentials, so mental action in the brain might well be sustained over 10^{-2} s or longer.

It is well known that PK results seem to be independent of the physical parameters involved, with the possible exception of cases where the parameters differ by multiple orders of magnitude [14]. The example of the tumbling cube, in which the effect of PK-ordered molecules is magnified to produce a macroscopic result at the endpoint of the cube's trajectory, provides a possible explanation. In the latter case, ordered molecules hit the cube and produce a small rotation Δq. The endpoint of the cube depends on a parameter s_0 which is proportional to $\log_2(\Delta q)$, with Δq dependent on the mass of the cube, its size, and the number of cubes affected [17,20]. Therefore, varying these parameters produces only a logarithmic change in s_0 and has very little effect on the outcome unless they are changed by several orders of magnitude. If PK is obtained in other cases from an original effect produced by ordered molecules, with that effect then substantially magnified, it would not be surprising if the final effect depended only logarithmically on physical parameters in the system. In that case PK effects would appear to be independent of these parameters when only small changes were made and would only show a dependence on them when changes were several orders of magnitude.

Conservation of Energy and Momentum

We saw in the previous section that provided mental action has an arbitrary aspect, with its physical effect not completely mathematically determined, it need not conserve energy. Similar considerations imply that in such case momentum need not be conserved either. Nevertheless, we expect that mental actions would deviate from conservation in only a very small way, as otherwise the deviations would be experimentally detectible.

In the present model molecules are ordered through quantum fluctuations produced within the limits of the uncertainty principle. These initial changes do not conserve energy and momentum, but are very small. These changes are then magnified by molecular interaction. However, this magnification is produced by dynamical interaction and therefore conserves energy and momentum. There remains the small net changes produced within the limits of the uncertainty principle. But molecules which are changed in direction are apt to be originally traveling in different directions, and therefore their small changes in momentum will tend to cancel out, with only a small remainder. Similarly, changes in the energy of each molecule will be small, and positive and negative changes will tend to cancel out, with only a small remainder.

These small remainders would come from the quantum vacuum, but would not ordinarily produce a detectible effect.

THE ARROW OF TIME

Because the dynamical equations of physics are time reversible, they have no need of a preferred direction in time. They describe observed processes whichever direction time is considered to flow. On the other hand, any new events, as defined herein, require a preferred direction, i.e., an arrow of time. Once a new event occurs, dynamical processes adjust to take into account the change introduced by it.

If we take new events to be quantum fluctuations in particle coordinates, as we have done herein, we must then trace back to these fluctuations to find the source of the arrow of time. As was mentioned earlier, quantum fluctuations in particle coordinates are usually considered to be the result of the action of vacuum photons on particles. In the usual conception of them vacuum photons arise from the vacuum, causelessly and randomly. They last for the time permitted to them under the uncertainty principle, and if they interact with any matter during that time, the interaction proceeds according to the dynamical laws. In this conception the new events would be the arising of these photons from the vacuum. So the direction of the arrow of time would be provided by the arising of these virtual photons [21].

However, there are several ambiguities to this picture. Given that the PK phenomenon also has ambiguities – over whether a phenomenon is PK or precognition [22] and assuming PK is present, whether it acts forward or backward in time [23] – it seems worthwhile to inquire further into the nature of ambiguities this model provides about the arrow of time.

For one thing, as Puthoff [24] has shown, vacuum radiation need not be viewed as photons which are created from the vacuum and annihilate themselves back into it. Rather, once vacuum radiation becomes established in its characteristic spectrum, perhaps early in the universe, it perpetuates itself deterministically with the same spectrum as it interacts with matter. Therefore, what appears to be photons arising out of the vacuum would be simply wave packets of radiation going in and out of phase. Of course, vacuum radiation appears and disappears within the limits of the uncertainty principle. So there does not appear to be any way to experimentally verify whether vacuum photons are causelessly created and annihilated or whether they travel deterministically in and out of phase. One might even conceive that the processes are complementary to each other, with perhaps a comparable complementarity between PK and precognition.

On the other hand, suppose we assume that photons are indeed created out of and annihilated into the vacuum. During any time segment dt, if we look at the array of vacuum photons interacting with a thermodynamic system, we can readily find which direction the arrow of time has. As we saw earlier, vacuum photons interact with particles to randomize their momentum distribution. In fact, that is the source of their thermodynamic entropy increase [3]. So the arrow of time points in the direction in which particle momentum is randomized.

But there is an ambiguity here. For one thing, there can always be some statistically rare array of photons that will order the momentum distribution of the particles, instead of randomizing it. So for that time segment, the arrow of time will point opposite to its usual direction. Furthermore, the fewer vacuum photons one looks at during any given time, the more common the reversals of the arrow of time become. And for a single photon there is no arrow of time because the concept, as applied to vacuum photons, is inherently statistical. It would seem that when the concept of an arrow of time is applied to phenomena taking place within the limits of the uncertainty principle, there can be a fundamental ambiguity as to its direction. Perhaps this ambiguity means that mental action also has a fundamental ambiguity about its relationship to the direction of time.

SUMMARY OF CONCLUSIONS

New Events

New events, i.e., those not predicted by the dynamical laws of physics, can be described as producing changes in the initial conditions of the dynamical trajectories of particles. Quantum fluctuations in the spatial and momentum coordinates of particles, within the limits of the uncertainty principle, can be regarded as new events. It can be shown that the cumulative result of momentum fluctuations in a molecule over a mean free path, when magnified by molecular interaction, can change the original direction of motion to any other direction, over a broad range of temperature and pressure. This random redistribution of momentum components can account for entropy increase in thermodynamic systems.

Mental Action and the Ordering of Quantum Fluctuations

We assume that mental action takes place through the ordering of the above random redistribution. It is shown that in the brain the impact of ordered water molecules in the intercellular medium can be used to break chemical bonds and thereby open ion gates and initiate an action potential. It takes about 80 water molecules to break an ionic or covalent bond. About 4000 ordered water molecules are needed to initiate a physical action.

The number of molecules influenced in mental action is twice the number of ordered molecules used in impact because the molecule which provides a magnification of the momentum change of an original molecule must also be influenced.

It may be that a given operator can simultaneously influence only a certain number of molecules and that this parameter can account for the limited effects any given operator can produce. (This number might rise when the operator is in a psychological state which is especially suited to produce PK, however.) For that reason it is of interest to compare the number of molecules which must be influenced to produce various mental actions.

If a sound wave (i.e., a wave which fluctuates in time and has a coherent phase across the target area) could be produced by PK, a sensitive microphone could be affected if about 10^4 molecules were influenced. Perhaps some people could produce such a coherent wave, so investigating whether a PK-produced sound wave could be detected by a microphone seems a possibly fruitful endeavor.

If a tumbling cube travels over a substantial distance, the endpoint of the trajectory is very sensitive to the original angular orientation of the cube. A pressure with the amplitude of a barely detectible sound wave would be sufficient to account for PK data on traveling cubes produced by Forwald. Of course, random influences would produce a scatter in the data, but statistical analysis can show the result of a pressure which is correlated with operator intention. It is not known whether Forwald's data, showing such a correlation, was due to PK or merely due to breath or hand movements which had such correlation. However, if the effect was due to PK, the number of molecules influenced to produce the needed air pressure would be about 2×10^5, a number not markedly different from the number (4,000 x 2 = 8,000) for free will.

A macroscopic object, such a tumbling cube, shows a PK effect because its final state is extremely sensitive to its initial conditions. In the case of the cube it can be shown that the PK effect has a logarithmic dependence on cube parameters, such as mass, size, and number of cubes affected. In general, according to the theory presented here, PK effects are originally produced at the molecular level, through the ordering of random molecular motions, and final effects, detectible at the laboratory (macroscopic) level, are produced through some process which greatly magnifies the original ordered motion. Because of this magnification the final effect will show only a very small, perhaps logarithmic, dependence on initial parameters involved in the ordering. So this theory predicts that PK effects in general will show little dependence on these parameters unless they are changed by several orders of magnitude.

The time over which mental influence must be exerted in any given action must generally be substantially longer than the time to travel a single mean free path (about 10^{-9} s in air). In the brain ion channels must be kept open long enough for ions to travel through them, and the influence must last at least 10^{-5} s. To account for Forwald's PK data on cubes, mental influence would have to last at least 10^{-2} s. (Otherwise, the number of molecules influenced would be higher.)

If the results of a mental action are not completely mathematically determined, but have some arbitrary element, energy and momentum need not be conserved in it. In the ordering process, some small amounts of energy and momentum might be contributed by or removed from the vacuum, but the amounts involved would generally be very small.

The Arrow of Time

New events, i.e., those not predicted dynamically, are inherently associated with an arrow of time. We are herein considering quantum fluctuations as examples of new events, and the source of these fluctuations is usually taken to be the random effects of vacuum photons. Therefore, the arrow of time associated with them must be traced back to the source of vacuum photons. There are two differing views: (a) they are created causelessly from the vacuum and are annihilated back into it, and (b) they are perpetuated indefinitely and only seem to be created and annihilated as wave packets go in and out of phase. The former is associated with an arrow of time; the latter is not. Perhaps this ambiguity in their source is related to the ambiguity between psychokinesis and precognition.

In the former scenario there is a further ambiguity in that the direction of an arrow of time with respect to vacuum photons can only be determined statistically by their interaction with a thermodynamic system, which in the forward direction of time picks up the disorder the vacuum photons convey. But on statistically rare occasions a set of vacuum photons may convey more order than disorder to a thermodynamic system and thereby reverse the local arrow of time. This implies that if an arrow of time is defined for phenomena that occur within the limits of the uncertainty principle, there is a fundamental ambiguity as to its direction. If mental action derives from the ordering of phenomena that take place within those limits, it too could reflect an ambiguity about the direction of time.

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