Quantum Fluctuations and the Action of the Mind

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Abstract. It is shown that if mental influence can change a position or momentum coordinate within the limits of the uncertainty principle, such change, when magnified by a single interaction, is sufficient to order the direction of traveling molecules. Mental influence could initiate an action potential in the brain through this process by using the impact of ordered molecules to open the gates of sodium channels in neuronal membranes. It is shown that about 80 ordered molecules, traveling at thermal velocity in the intercellular medium in the brain, can break an ionic or covalent bond, and that the number needed to initiate an action potential is relatively small. If mental influence can act within the brain, it is reasonable to suppose it can act to some extent outside of it. If mental influence could not only order the direction of individual molecules, but coordinate this effect to produce a longitudinal pressure wave which is reasonably coherent across a macroscopic surface, only 10^4 molecules need be simultaneously affected to produce a detectible sound wave. Such an effect is not ordinarily observed, which suggests that if mental influence acts by ordering the direction of molecules, it acts at the level of individual molecules, but does not coordinate their motion.

Keywords: Mind, Uncertainty principle, Quantum fluctuations

1.   Introduction

This paper proposes that mental influence takes place within the limits of the uncertainty principle, by ordering quantum fluctuations that take place within those limits. It draws upon the stochastic interpretation of quantum mechanics (Chebotarev, 2000; de la Peña & Cetto, 1996; Jammer, 1974), which says that all particles are subject to these fluctuations. These cause a particle to make a random walk about its unperturbed trajectory, and cause its momentum components to redistribute in a random way, with the total momentum and energy of all interacting particles remaining constant (Burns, 1998). The change in momentum components of a particle over a mean free path is small. However, this change is magnified when the particle undergoes a molecular interaction, and this magnified change can account for entropy increase in thermodynamic systems (Burns, 1998, 2002b).

It is proposed in this paper that mental influence acts by ordering these quantum fluctuations, with the size of these effects being the root mean square values of the above fluctuations in position and momentum. Thus instead of making a random walk a particle can move in a particular direction, and instead of having a random redistribution of momentum components, a particle can be directed to travel in a certain direction. This ordering could thereby be thought of as coming from the proverbial "Maxwell's demon" which produces entropy decrease.

We will also inquire herein as to the number of ordered molecules, traveling at thermal energy, that would be required to open ion channels and thereby produce action potentials in the brain. We will see that the number is relatively small.

It is reasonable to suppose that if mental influence can act in the brain, it can also act outside the brain. Indeed, many careful experiments in parapsychology have shown that mental influence can produce an ordering in random physical processes, although this effect is so small that statistical analysis of many thousands of trials are needed to show it (Radin, 1997). The fact that this effect is small implies that some factors may ordinarily limit its magnitude, and we will use the fact that it is not readily observed to explore what some of these limiting factors may be. We first calculate how much pressure can be produced when a given number N_I of molecules are simultaneously influenced. We will next use the fact that mental influence is not readily detected in low pressure environments to rule out one possible limiting factor. We

will then use the fact that mental influence is not readily detected by microphones to explore some other possible limiting factors.

We should note that several researchers, Walker (1975) and Eccles (1970), have previously suggested that free will acts within the limits of the uncertainty principle. Walker's proposal was made within the context of wave function collapse and was applied to the action of psychokinesis on traveling cubes. This proposal will be discussed further elsewhere (Burns, 2002a). Eccles proposed that free will can act through changes in position of synaptic vesicles within the limits of the uncertainty principle. However, Wilson (1999) has shown that action potentials cannot be initiated by changes in the cellular substructure within these limits because the combination of energies and times involved are too large. Thus if mental influence acts within the limits of the uncertainty principle, it must generate action potentials by the ordering of many small molecules (Burns, 1999), and that is the idea being explored herein.

2.   The Stochastic Interpretation of Quantum Mechanics

The stochastic interpretation of quantum mechanics holds that particles (and objects) constantly undergo fluctuations within the limits of the uncertainty principle (Chebotarev, 2000; de la Peña & Cetto, 1996; Jammer, 1974). It can be understood in the following way. The Schroedinger equation for a free particle,

$$i\hbar\, \frac{\partial \mathbf{y}}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2 \mathbf{y}\ ,\tag{1}$$

where $\mathbf{y}$ is the probability amplitude, has a form similar to the diffusion equation,

$$\frac{\partial f}{\partial t} = D\nabla^2 f\ ,\tag{2}$$

with diffusion constant D, which can represent the stochastic motion of an ensemble of particles, where f is the probability density of the particles (Haken, 1983). And, in fact, a variety of analyses have shown that the Schroedinger equation can be viewed as describing stochastic motion with a diffusion constant $D = \hbar/2m$, where m is the mass of the particle (Chebotarev, 2000; de la Peña & Cetto, 1996; Jammer, 1974). From the usual relationship between the diffusion constant and the root mean square coordinate drift, $\mathbf{d}x = (2Dt)^{1/2}$ (Haken, 1983), we obtain

$$\mathbf{d}x = (\hbar/m)^{1/2} t^{1/2}\ .\tag{3}$$

In a similar vein, Abbott and Wise (1981) have shown that if the motion of a particle is limited by the uncertainty principle, it will follow a trajectory of fractal dimension two, which is equivalent to brownian motion. We must understand that because this motion is quantum in nature, such a path cannot be regarded as a classical brownian trajectory, with position and momentum simultaneously known. Nevertheless, the root mean square variations in these coordinates can be simultaneously specified.

We can obtain $\mathbf{d}p_x$, the root mean square value of shift in momentum, from the limit of the uncertainty principle,

$$\mathbf{d}x\,\mathbf{d}p_x = \frac{\hbar}{2}\ .\tag{4}$$

We find

$$\mathbf{d}p_x = \frac{1}{2}(\hbar m)^{1/2}\, t^{-1/2}\ .\tag{5}$$

Similar equations hold for the y and z components of motion. Further analysis shows that the fractional change in each momentum component, dp_x/p, where p is the total momentum, and the fractional change in energy E are proportional to $t^{1/2}$ (Burns, 1998). So energy and momentum tend to be conserved when t is large.

In the past it has been commonly held that these fluctuations are merely a mathematical artifact of the equations of quantum mechanics, with only a minority proposing that such fluctuations have physical reality (Jammer, 1974). However, in recent years it has been shown that vacuum radiation produces brownian motion in particles with the same diffusion constant as that above (Rueda, 1993a, 1993b). Therefore these fluctuations are physically real. From the standpoint of the Schroedinger equation this motion can be viewed as irreducible quantum fluctuations. However, if vacuum radiation is taken into account, they can be attributed to the random action of this radiation.

3.   The Ordering of Quantum Fluctuations Through the Action of the Mind

This paper proposes that mental action takes place through the ordering of quantum fluctuations, with the maximum change that can be produced in any given particle coordinate being the same as the root mean square variation given by equations (3) and (5) above. We further assume that mental influence can select the most favorable change for a particle to produce a given effect within the above limits.

There are two ways in which the direction molecules travel can be affected: by changing the momentum components directly or by changing spatial coordinates. We will first inquire about changing a momentum component. For the sake of seeing how the process works, we will start with a specific example and then generalize. It has been shown (Burns, 1998) that in a mean free path l of travel in air at standard conditions, random quantum fluctuations produce a change in each momentum component of $dp_x/p = 1.2 \times 10^{-3}$, where p is the magnitude of the momentum. The molecular interaction at the end of the mean free path multiplies each change by a factor l/r, where r is the molecular radius. In air at standard conditions $l/r = 1.0 \times 10^4$, so after interaction $dp_x/p > 1$. In this way the magnitude of each momentum component is randomized after one mean free path.

Further analysis shows that this redistribution of momentum components takes place in only one collision time in all thermodynamic systems, except those at very high pressure (Burns, 1998). (Even at high pressure the randomization takes place, but then requires several collision times.) It is this randomization, produced by quantum fluctuations, which produces entropy increase in thermodynamic systems (Burns, 1998, 2002b).

In order for a molecule to be ordered in its direction of travel, it is only necessary that the initial shift in momentum component, instead of being random, be such that after the next interaction the molecule travels in the desired direction. Therefore, a molecule can be ordered (except at very high pressure) in one mean free path.

Now let us investigate changing the direction of travel by shifting the spatial coordinate. We will assume that the molecular interaction is of a repulsive, "hard-sphere" nature such that the range is about the same as the radius r of the cross section $s = p \, r^2$. If the molecules strike completely head on, each molecule will be turned by $180°$. On the other hand, if the centers of the molecules are separated by $2r$ at nearest approach, the molecules will pass on by unaffected. Therefore, if the coordinate dx of a given molecule can be shifted by $4r$ to the right, say, during the collision time t, it can be reflected repulsively to the right at any angle from 0 to $180°$. Similarly, if the molecule is shifted by $4r$ to the left during time t, it can be shifted repulsively to the left through that range. Therefore, it can be shifted to any direction of travel if $dx(t) > 4r$. We use equation (3) and define a constant $x = [\hbar p t / 16 m s]^{1/2}$, and this condition now becomes $x > 1$. Utilizing equation (A.2), the collision time for air at standard conditions, and various other constants in Appendix A, we find $x = 5.79$. Therefore, the condition is satisfied in air at standard conditions, and similarly is satisfied at standard temperature for any pressure less than atmospheric (because t is inversely proportional to pressure). So the direction of travel of a molecule can be ordered through shift of a spatial coordinate in one mean free path in air for these conditions.

In summary, the direction of travel of a molecule can be ordered through redistribution of momentum coordinates in one mean free path. (If the pressure is very high, several mean free paths are

needed.) If molecular interaction takes place via a "hard-sphere" repulsive interaction (and cross section not substantially larger than that in air), this ordering can also take place within one mean free path via shift of spatial coordinate, at standard temperature and standard pressure or lower. In each case an interaction with another molecule to magnify the effect of the above fluctuations is a necessary part of the process.

4.   The Number of Ordered Molecules to Produce an Action Potential in the Brain

Wilson (1999) has described in some detail the conditions necessary to produce an action potential in the brain. It can be produced by opening sodium channels in the neuronal membrane, and a channel is opened by changing the conformation of an arm of a protein molecule which forms a gate to the channel. To change the conformation there must be sufficient energy available to break the relevant chemical bonds. It takes 3.3×10^{-13} erg to break a hydrogen bond, and the energy of a typical ionic or covalent bond is about 15 times that, or 5.0×10^{-12} erg (Wilson, 1999).

Let us suppose that the arm to be moved has a mass M and that n lighter molecules (probably water molecules) having mass m can be ordered such that each one strikes the arm head-on. The velocities of the small molecules before and after collision are v and $-v'$, respectively (the minus sign indicating reversal of direction). Before impact the velocity of M is zero; after impact it is V. Conservation of energy and momentum tells us that

$$\frac{n}{2}mv^2 = \frac{n}{2}m(v')^2 + \frac{M}{2}V^2 \ ; \tag{6}$$

$$nmv = -nmv' + MV \ . \tag{7}$$

This yields the equations $MV^2 = nm(v-v')(v+v')$ and $MV = nm(v+v')$. Dividing one by the other we find that $V = v-v'$. We can substitute in the momentum equation to find v' and then find V. We then find that the energy $E_M = (1/2)MV^2$ imparted to the arm is given by

$$E_M = 4n^2(\frac{1}{2}mv^2)\frac{m}{M}\frac{1}{(1+nm/M)^2} \ . \tag{8}$$

The small molecules have thermal energy, so we write $1/2mv^2 = E_{th}$. Then $n^2 = (M/m)(E_M/4E_{th})(1+nm/M)^2$. Taking the square root of both sides and solving for n, we find

$$n = \frac{(E_M/4E_{th})^{1/2}(M/m)^{1/2}}{1-(E_M/4E_{th})^{1/2}(m/M)^{1/2}} \ . \tag{9}$$

We have $E_M = 5.0 \times 10^{-12}$ erg (the value to break a chemical bond) and $E_{th} = 3/2kT = 6.07 \times 10^{-14}$ erg. If $M/m = 100$, then $n = 83.1$. We conclude that, in round numbers, about 80 molecules must be ordered to provide sufficient energy to break a single ionic or covalent bond. If five bonds must be broken, then 400 ordered molecules would be needed to open the gate.

It is usually necessary to open more than one sodium channel to produce an action potential (Wilson, 1999). Furthermore, initiating a physical action in the body probably requires more than one action potential in the brain, although the number needed is not presently known (Wilson, 1999). If we multiply by 10 to estimate the effects of these factors, then about 4,000 molecules would have to be ordered to initiate a physical action.

5.   The Pressure Produced by Ordered Molecules

We will assume that mental influence not only can act in the brain, to influence neural processes, but also to a small degree outside the brain. And, as an example of such action, we now wish to find the pressure ΔP which could be produced by ordering molecules in air (or any other gas).

When molecules of a gas have a random distribution of momentum, each degree of freedom shares equally in the energy, and a given velocity component, v_y, say, equals $(kT/m)^{1/2}$. The pressure $P = 1/2n(2mv_y)v_y = nkT$, where n is the number of molecules per unit volume. Let n_{ord} be the number of molecules per unit volume ordered by mental influence. We have v'_y, the velocity of the ordered molecules, $= [v_x^2 + v_y^2 + v_z^2]^{1/2}$. Therefore,

$$v'_y = (3kT/m)^{1/2} , \tag{10}$$

and the partial pressure produced by these molecules is $n_{ord}(2mv'_y) v'_y = 6n_{ord}kT$. Thus the excess pressure ΔP is

$$\Delta P = n_{ord}(5kT) . \tag{11}$$

6.   The Number of Molecules N_I Which Are Simultaneously Influenced
to Produce ΔP -

Let us now ask how many molecules N_I a person must simultaneously influence to produce ΔP . We have seen earlier that (unless the pressure is very high) the direction of travel of a molecule can be ordered in one mean free path. More specifically, a molecule undergoes a shift in spatial or momentum coordinates as it travels the mean free path, and this shift is then magnified by an interaction at the end of the path.

Because the molecules are subject to continuous random fluctuations, a person must act on each molecule she is ordering throughout the mean free path l . Therefore, the number of molecules she is simultaneously ordering is $n_{ord} l A$, where A is the cross-sectional area that ΔP acts on. The molecules that the latter molecules interact with will end up traveling more or less in the opposite direction, so their final direction does not matter. However, they have to be kept in a suitable position during the interaction, so the ordered molecules can be properly influenced. Therefore, $N_I = 2n_{ord} l A$. Using equations (11) and (A.1), we find

$$N_I = \frac{\sqrt{2}p \, A \Delta P}{20 s \, P} . \tag{12}$$

7.   Mental Effects May Be Limited by the Number of Molecules N_I
a Person Can Simultaneously Influence

The effects of mental influence outside the body must be small because they are not ordinarily observed. The reason they are small may be that a person can simultaneously influence only a relatively small number of molecules, or perhaps there is some related limitation. N_I is a measure of the amount of information a person exerting mental influence deals with at any given time. However, just as the output of a computer could be limited either by the amount of information which can be processed at a given time or by the processing rate, a person might be limited by N_I, the rate N_I/t , where t is the collision time, or some other function involving N_I and molecular quantities such as l or t .

We can eliminate the possibility that the magnitude of mental effects is limited by the rate N_I/t by considering what happens when pressure is varied. If N_I/t is a limiting constant, independent of pressure and temperature, the excess pressure ΔP a person could produce would be proportional to $T^{1/2}$ and independent of pressure (by equations (12) and (A.2)). Then ΔP could become comparable to the ambient

pressure in low pressure environments, and effects of mental influence could be frequently observed. But such is not the case.

On the other hand, the possibility that N_I is a limiting constant is consistent with mental effects outside the body seldom being observed because then ΔP is proportional to pressure and independent of temperature. Therefore, if $\Delta P / P \ll 1$ at atmospheric pressure, as we expect, such will continue to be true at low pressure.

It is known from studies of psychokinesis (mental influence outside the body) in parapsychology that (a) some persons produce larger effects than others, and (b) the effects any given person produces vary somewhat according to mood and other psychological factors (Broughton, 1991). So if N_I is the limiting factor, we would expect its value to vary from person to person, and that the value for a given person would vary somewhat according to psychological factors.

8. Detection of a Fluctuating Pressure Wave by a Microphone

As noted previously, if molecules can be ordered inside the brain, it seems likely that they can be ordered outside it also. On the other hand, effects of mental influence are not observed in measuring instruments used in physics and engineering, and this may shed light on limitations on the size or type of effects which can be produced outside the brain. In particular, microphones are very sensitive to pressure waves, yet are not observed to show effects of mental influence. So let us now inquire as to what factors would be involved in the detection of such influence by a microphone.

We first ask the number of molecules necessary to produce a pressure wave at the detection threshold of a microphone. Many ordinary microphones can detect a sound level of 30 db (6.3×10^3 dyne/cm^2), and a low noise microphone can detect -2.5 db (1.5×10^{-4} dyne/cm^2).[1] Using equation (12) and constants from Appendix A, and setting $A = 0.10 \, \text{cm}^2$, we find that $9.37 \times 10^3 \approx 10^4$ molecules must be simultaneously influenced to produce a pressure of -2.5 db.

By comparison, we estimated in Section 4 that a physical action can be initiated by 4×10^3 ordered molecules. Therefore, the number of molecules influenced is twice that, or 8×10^3. The number of molecules which must be simultaneously influenced to affect a microphone is about the same as the latter number, yet no effect is detected in a microphone. So let us now ask what factors are relevant to detection of a pressure wave by a microphone and whether any of these might account for the lack of detection of mental influence.

(1) Perhaps the number of molecules which can be influenced outside the brain is much less than the number that can be influenced inside it. However, reports in the parapsychology literature (Radin, 1997) that mental influence can produce a small, but statistically detectible, effect on macroscopic objects make it seem unlikely that the small number of molecules needed to affect a microphone could be a limiting factor.

(2) The ordering of individual molecules takes place at a time scale of 10^{-9} seconds. In order for a microphone to detect a pressure wave, it should vary through at least one cycle, and this would require about 5×10^{-5} seconds in the higher audio range. However, in order to produce an action potential, sodium channels in the brain must remain open long enough for ions to pass through them, and channels remain open at least 10^{-5} seconds (Wilson, 1999). Thus even after the initial impacts to open a sodium channel, continuing impacts to keep it open are probably needed for that length of time. Besides, if a succession of volitional acts are performed, mental influence would then act for a considerably longer time than 10^{-5} seconds. So the possibility that affecting a microphone is limited by time constraints seems unlikely.

(3) It may be that mental influence cannot produce a time variation which has much regularity. However, even if the time variation is very irregular, provided it lasts at least 10^{-5} sec, broad spectrum noise would be produced.

(4) In order for a microphone to detect a pressure wave, it must be more or less coherent across its cross-sectional area. In other words, if mental influence can produce regular or irregular time variation at any given area at the molecular scale, but the phases of the waves produced at different molecular-scale locations vary randomly, the net result would not show any variation at the macroscopic scale of a microphone and so would not be detectible by it. So the explanation for the lack of detection may be that mental influence cannot produce a wave which varies coherently across the surface of a microphone.

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[1] $I(\text{dB}) = 20 \log_{10}(p/p_0)$, where $p_0 = 2 \times 10^{-4}$ dyne/cm^2.

We have so far assumed that mental influence can order direction of travel in a rather precise way, and have assumed that ordered molecules strike a surface head-on. But the process may in fact be quite rough. Indeed, to break a chemical bond in a molecular gate in the brain, no special time variation is needed, but only enough collisions from ordered molecules to impart the necessary energy. Furthermore, these ordered molecules need only target a surface of molecular size, and there is no need for coordinated motions across any larger area.

So assuming mental influence exists and that it acts by ordering the direction of molecules, as proposed here, the last item may provide the explanation of why it is not detected by microphones.

9. Summary and Discussion

It is not known whether mental influence exists, or if so, how it produces its effects. However, this paper proposes that mental influence acts within the limits of the uncertainty principle and explores the consequences of that idea.

In doing so, this paper draws on the stochastic interpretation of quantum mechanics, which holds that all particles are subject to fluctuations within the limits of the uncertainty principle, with root mean square variations in position and momentum coordinates as specified in equations (3) and (5). It proposes that mental influence acts by ordering these quantum fluctuations, such that their root mean square variations specify the upper limits of mental influence. However, mental influence can act to select the most advantageous change within these limits.

The coordinate shifts produced along a mean free path by these fluctuations are relatively small. However, the effects of these shifts are highly magnified in an interaction with another molecule. In this way, the direction of a molecule can be changed to a desired direction by making a small coordinate shift within the above limits and then magnifying that shift in the next molecular interaction. The coordinates of the second molecule must also be influenced to make the proper change to the first. Therefore, the number of molecules influenced is two times the number which are ordered.

Within the brain about 80 ordered molecules, traveling at thermal velocity, provide sufficient energy to break an ionic or covalent bond. (These would presumably be water molecules in the intercellular medium.) Opening a molecular gate to a sodium channel probably requires breaking several bonds; more than one channel usually needs to be opened to produce an action potential; and initiating a physical action probably requires more than one action potential. Taking these factors into account we estimate that about 4,000 molecules would need to be ordered to initiate a physical action.

Just as a computer might be limited by either the amount of information it is dealing with at one time or by the rate of information processing, mental influence might be limited by the number of molecules N_I it can simultaneously influence during a time t or by the processing rate N_I/t . The fact that effects of mental influence are not readily detectible at low pressures was shown to eliminate the latter possibility. However, N_I may be a limiting factor.

To affect a low noise microphone at the threshold of detection (-2.5 db) would require, for a cross-sectional area of 0.1 cm^2, that $N_I \approx 10^4$ molecules. Low noise microphones are in common use, yet effects of mental influence are not ordinarily detected by them, so (assuming mental influence can order the direction of molecules, as proposed here) some limiting factor must come into effect. It may be that the ordering of molecules by mental influence is only done in a very rough way, such that a coherent signal cannot be produced across the macroscopic surface of a microphone.

Nevertheless, if mental influence can order molecules as is proposed herein, and can do this outside the brain as well as within it, it is reasonable to expect that it could produce effects such as increase or decrease of pressure or temperature which do not involve any coherent action between the ordered molecules. Such effects should be detectible by sensitive instruments, although statistical analysis might be required to show them if factors from random noise are also present.

APPENDIX A   Basic Equations for an Ideal Gas

In an ideal gas, $P = nkT$ and $E = 3/2 \ kT$, where

P	=	pressure;
n	=	number of molecules per unit volume;
k	=	Boltzmann's constant (= 1.38×10^{-16} erg K^{-1});
T	=	absolute temperature;
E	=	average energy per molecule.

We note that (Huang, 1963) $l = \bar{v} t$, where $\bar{v} = (2kT/m)^{1/2}$, and

$$l = \frac{\sqrt{2\pi}}{8} \frac{kT}{Ps} ;$$

(A.1)

$$t = \frac{\pi^{1/2}}{8} \frac{m^{1/2}}{s} \frac{(kT)^{1/2}}{P} .$$

(A.2)

where

l	=	mean free path;
$\bar{v}$	=	most probable velocity;
t	=	time between interactions in the gas;
m	=	mass of a molecule;
s	=	molecular cross section.

In air, $s = 1.98 \times 10^{-16}$ cm^2, and $m = 2[.8(14) + .2(16)] m_{\text{H}} = 28.8 \, m_{\text{H}}$, where

m_{H}	=	mass of a hydrogen atom (= 1.67×10^{-24} gm).

At standard conditions ($P = 1.013 \times 10^{6}$ dyne/cm^2, $T = 20°\text{C} = 293°\text{K}$), $l = 6.33 \times 10^{-5}$ cm, and $t = 1.544 \times 10^{-9}$ sec.

$\hbar$, Plank's constant divided by 2π , equals 1.054×10^{-27} erg sec.

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