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The Effect of Ordered Air Molecules on a Tumbling Cube

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Abstract. A quantitative theory of the effects of mental influence outside the body, based on the idea that such influence consists of the ordering of random fluctuations within the limits of the uncertainty principle, is used to predict the effects of ordered air molecules on a tumbling cube. If the influence can act throughout the first tumble of a cube, the pressure necessary to produce the deviation effects achieved by Forwald (1959, 1969) is estimated to be 1.45×10^{-5} dyne/cm^2. The number of molecules which must be simultaneously influenced to produce this pressure is 2.41×10^5.

The trajectory of a tumbling cube must have a minimum number of steps s_0 in order for any substantial amount of magnification of a change in its trajectory to occur. (A step is a tumble from one corner to another.) When mental effects are produced by ordered molecules, s_0 depends logarithmically on cube parameters (mass, length of a side, velocity), the pressure of the surrounding gas, and the number of molecules a person can simultaneously influence. If a cube of mass M and half-length b is compared to a cube with mass M_1 and half-length b_1, and all other parameters are constant, then $s_0(M,b) - s_0(M_1,b_1) = \log_2(Mb_1^2/M_1b^2)$. If different numbers of cubes n and n_1 are influenced, with all other parameters constant, then $s_0(n) - s_0(n_1) = \log_2(n/n_1)$. If values for s_0 are compared at pressures P and P_1, with all other parameters constant, then $s_0(P) - s_0(P_1) = \log_2(P_1/P)$.

Keywords: Mental effects, Randomness, Tumbling cube, Uncertainty principle

1. Introduction

In a previous paper (Burns, 2002b) it was shown that the endpoint of a tumbling cube is extremely sensitive to its initial angular orientation, in that a very small change in this orientation can produce a substantial sideways deviation ΔY in endpoint of its trajectory. It was pointed out that even if the action of mental influence is very small, it could use this magnifying effect to change the endpoint of dice thrown in games of chance, and thereby produce "lucky" results. However, in order to keep the analysis very general, no specifications were made in the previous paper as to the size of the initial change. In the present paper we now incorporate a proposal made elsewhere (Burns, 2002a) that mental influence acts within the limits of the uncertainty principle, and ask the implications of these combined ideas.

Specifically, we will examine two possibilities. First, we will suppose the cube shifts by the amount permitted by the uncertainty principle for its macroscopic mass. The proposal that mental influence acts in this way was originally made by Walker (1975), and he concluded, using a rough dynamical analysis of the cube's trajectory, that the experimental results of Forwald (1959) could be explained by this hypothesis. However, we will see herein, drawing on the more detailed dynamical analysis of Burns (2002b), that neither Forwald's results nor anecdotal results can be explained in this way. Therefore, if mental influence acts within the limits of the uncertainty principle, some other mechanism must be involved.

In this regard, it has been shown (Burns, 2002a) that if a freely-traveling molecule shifts its momentum components within the limits of the uncertainty principle and these changes are then magnified by interaction with another molecule, its direction of travel can be changed to any direction in one mean free path. In this way, if mental influence can make changes within the limits of the uncertainty principle, it can order the direction of travel of a molecule (Burns, 2002a). So, second, this paper will explore the idea that mental influence acts on tumbling cubes (dice) by means of ordered air molecules, and we will compute the pressure and number of influenced molecules necessary to account for Forwald's (1959, 1969) results.

The rest of this paper is organized in the following way. In Section 2 we will review previous conclusions about quantum fluctuations in spatial and momentum coordinates, using the stochastic interpretation of quantum mechanics. In Section 3 we will review previous conclusions about the dynamics of a tumbling cube.

In Section 4 we will use the above results to compute the shift in angular orientation allowed to a cube of macroscopic mass M within the limits of the uncertainty principle. We will see that a cube would have to travel 68 cm to show any substantial sideways deviation from that angular shift, yet Forwald obtained results in less than 50 cm. So the angular shift would have to be larger than allowed by the above condition to account for Forwald's results.

In Section 5 we will find the number of air molecules N_I which must be influenced to produce a pressure ΔP on a cube at the beginning of its trajectory, and in Section 6 we will relate ΔP to the minimum number of steps s_0 a cube must travel to produce a substantial deviation ΔY in the endpoint of its trajectory. In Sections 7 and 8 we will estimate the minimum pressure ΔP and the minimum number of molecules N_I which must be influenced to explain Forwald’s (1959, 1969) experimental results. In Section 9 we will compare these numbers with analysis made elsewhere (Burns, 2002a) of the number of molecules which must be influenced to produce an action potential in the brain and to produce a detectible signal in a low-noise microphone.

In Sections 10, 11 and 12 we will find the dependence of the deviation ΔY in endpoint of the trajectory on cube parameters, such as size, mass, and number of cubes simultaneously affected, and find that the deviation depends on these logarithmically. This logarithmic dependence could account for the seeming independence of results on these parameters which is reported in psychokinesis (PK) experiments (Stanford, 1977).

Finally, a summary of results is provided in Section 13.

2. Quantum Fluctuations and the Uncertainty Principle

According to the stochastic interpretation of quantum mechanics (Chebotarev, 2000; de la Peña & Cetto, 1996; Jammer, 1974), all particles and objects are subject to quantum fluctuations within the limits of the uncertainty principle, i.e., root mean square values of spatial and momentum coordinates are limited by

$$dx dp_x = \hbar / 2 \, , \tag{1}$$

where $\hbar$ is Planck’s constant divided by $2 p$. Individual root mean square values are given by

$$dx = (\hbar / m)^{1/2} t^{1/2} \; ; \tag{2}$$

$$dp_x = \frac{1}{2} (\hbar m)^{1/2} t^{-1/2} \; , \tag{3}$$

where t is the time and m is the mass of the particle or object (Burns, 2002a). Identical limits can be derived by assuming that a root mean square change in coordinate produces the same change in the action integral, regardless of which coordinate is shifted (Burns, 1998).

We further note that the fractional change on each momentum component, dp_i / 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 are conserved when t is large.

It has been proposed in a previous paper (Burns, 2002a) that mental influence can act by ordering quantum fluctuations, with the maximum change in each coordinate being the same as the above root mean square variation. It was further proposed that mental influence can act to select the most favorable change within these limits to produce the desired effect.

3. Dynamics of the Tumbling Cube

It was shown in a previous analysis (Burns, 2002b) that for a cube traveling forward in the x direction, a small shift Δq in its initial angle of orientation q will produce an average shift ΔY in the endpoint of the trajectory, with relationships between Δq and ΔY as follows.

$$\Delta Y = a(s - s_0)\,; \tag{4}$$

$$s_0 = \log\left[\frac{p/3}{\Delta q}\right]/\log 2\,, \tag{5}$$

where a is the average sideways step length during each tumble, s is the total number of steps, and s_0 is the minimum number of steps the cube must travel to show any substantial magnification of the shift Δq. (A step is a tumble from one corner to another.) If Δq increases in an ongoing process which is longer than t_{cube}, then Δq is evaluated as $\Delta q\ (t_{cube})$. (In a more exact formulation, the term $\Delta q\ (t_{cube})$ would be multiplied by a factor near unity which depends on the details of the time dependence of the mental influence on the cube. However, since we always take the log of this term, the factor near unity can be omitted.)

We should note that a cube can travel forward by either tumbling (rotating about successive corners) or bouncing (spending most of its time airborne). Equations (4) and (5) and associated discussion above apply to both tumbling and bouncing (Burns, 2002b). Most of the rest of the paper will pertain to tumbling cubes, but we will sometimes refer back to the bouncing case.

We would like to know the time t_{cube} for one step. We have seen elsewhere (Burns, 2002b) that for a tumbling cube this quantity has a simple relationship to the cube parameters when a term $z \geq 1$, where

$$z = \frac{u/62.2}{b^{1/2}(\cos i)^{1/2}} \quad \text{cm}^{1/2}\text{/sec} \tag{6}$$

b is the *half-length* of the cube (i.e., the length of a side is $2b$), u is the average forward velocity, and i is the angle of inclination of the surface the cube travels on. Typically cubes which acquire their velocity by tumbling down a ramp, as might be done in a PK experiment, fulfill this condition over much of their trajectories (Burns, 2002b). When $z \geq 1$,

$$t_{cube} = \frac{2p}{3}\frac{b}{u}\,. \tag{7}$$

We will also need another relationship which holds when $z \geq 1$,

$$X = b\sqrt{3}\,s\,, \tag{8}$$

where X is the distance of forward travel.

4. Shifting a Cube of Mass *M* Within the Limits of the Uncertainty Principle

As noted earlier, Walker (1975) proposed that mental influence acts within the limits of the uncertainty principle and that it acts to affect a traveling cube by shifting its initial angular orientation, with the effect of this shift being magnified by the subsequent trajectory of the cube. He further proposed that the magnitude of the angular shift was the amount allowed by the uncertainty principle for the cube's macroscopic mass. (He did not consider the possibility that ordered air molecules could strike the cube and produce an angular shift.) Using a somewhat rough dynamical analysis, Walker concluded that such a shift could account for the deviation in Forwald's (1959) experiments with traveling cubes. Let us now recompute the deviation using the present, more detailed analysis. (For a comparison of Walker's analysis with the present one, see Appendix A.)

The distance from a corner of the cube to the center of mass is $b\sqrt{3}$, so the angular shift is the change in spatial coordinate divided by $b\sqrt{3}$. By equation (2) the angular shift $\Delta q\ (t_{cube})$ which produces the final sideways deviation of the cube is given by

$$\Delta q\,(t_{cube}) = \left[\frac{\hbar t_{cube}}{M}\right]^{1/2} \frac{1}{b\sqrt{3}} . \tag{9}$$

The cubes used in Forwald's (1959, 1969) experiments typically had a mass of 5 gm and a half-length of 0.8 cm.

We need an estimate of t_{cube} and therefore of the forward velocity u in the initial stages of the trajectory. In these experiments the cubes dropped to a ramp from a small height, and then tumbled and bounced down the ramp to a horizontal surface. Forwald set the forward velocity equal to 186 cm/sec at the bottom of the ramp (the latter computed from the height the cubes traveled down the ramp). The derivations of equations (4) and (5) assume that the steps the cubes take are regular and similar in length (Burns, 2002b). This was not strictly true of Forwald's cubes, and the above implies that we should estimate a typical value for u in the first part of the trajectory, rather than a specific value for the first bounce (which is unknown in any case). This value must be somewhat less than the value at the bottom of the ramp, and we set u = 100 cm/sec. The latter figure is not well known, but in computing s_0 (equation (5)) we will be taking its log. Therefore, s_0 is not sensitive to this value. (Doubling or halving u will only change s_0 by half a step.)

As discussed in Burns (2002b, Section 7), $z \geq 1$ over most of the trajectory in these experiments, and we can use equations (7) and (8). By equation (7) and the above cube parameters, t_{cube}, the time for one tumble, equals $1.676\text{x}10^{-2}$ sec. Therefore, $\Delta q\ (t_{cube})$ = $1.356\text{x}10^{-15}$ radians. By equation (5) the minimum number of steps s_0 for which any substantial deviation ΔY can be produced is 49.4. Using equation (8) we find that the forward distance of travel X_0 corresponding to s_0 steps is 68.5 cm.

Forwald's cubes typically traveled 15 cm down a ramp (McConnell & Forwald, 1968) plus 35 cm across a horizontal surface, for a total of 50 cm. The deviation ΔY was typically about 5 cm, large enough that his results would correspond to the range of forward travel where s was larger than s_0. But the distance X_0 above is larger than 50 cm. So a shift in angular orientation of the cube, to the extent permitted by the uncertainty principle for an object of its macroscopic mass, cannot account for Forwald's experimental results. Furthermore, anecdotal accounts suggest that "lucky" results with dice can occur in much shorter distances than 50 cm.

For these reasons, it appears that Walker's (1975) conclusion that mental intention acts via shifts in position of the size allowed by the uncertainty principle for macroscopic mass is not correct. His dynamical analysis was simply too rough to show accurately the minimum distance of travel needed.

However, Walker's results are important, in that he was the first to show that a traveling cube could exponentially magnify small changes at the beginning of a trajectory to produce substantial sideways deviation at its end, and that mental influence might be a very small effect which could produce such results through magnification. He was also one of the first to propose that mental influence can act within the limits of the uncertainty principle.

Since experimental results and anecdotal accounts cannot be explained in the above way, we must look further. Molecules are much less massive than macroscopic objects, and by equation (2) they can be affected within the limits of the uncertainty principle much more readily. So we will next inquire as to what effects can be produced by ordered air molecules which produce a small angular shift in cube position during the initial steps of the cube trajectory.

5. The Pressure ΔP Produced by Ordered Molecules

It has been shown elsewhere (Burns, 1998) that when the root mean square fluctuations in momentum of a traveling molecule are magnified by interaction with another molecule, its momentum components are redistributed to random values (with total momentum constant) after one mean free path of travel. In this way quantum fluctuations can account for entropy increase in thermodynamic systems (Burns, 1998, 2002c).

As noted in Section 2, we are assuming that mental influence can act to select the most favorable change within the above root mean square limits. In order for a molecule which has a component of motion directed toward a surface to produce a greater pressure than it originally would have, it is only necessary that momentum components be redistributed such that the molecule travels directly toward the surface. Thus it is only necessary for a molecule to travel one mean free path, including an interaction at the end of the path to magnify the previous momentum changes, for mental influence to order its direction of travel to the desired direction (Burns, 2002a).

Furthermore, as has been discussed elsewhere (Burns, 2002a), because the randomizing action of quantum fluctuations takes place continuously, each molecule to be ordered must be influenced over the entire mean free path. Also, because an interaction at the end of the mean free path is necessary to magnify the momentum redistribution, the number of molecules which must be simultaneously influenced is twice the number being ordered at any given time.

It has been shown elsewhere (Burns, 2002a) that the excess pressure ΔP produced by the ordered molecules is related to the number of molecules N_I which must be simultaneously influenced by

$$\Delta P = \frac{20\, s\; P N_I}{\sqrt{2p}\; A}\,, \qquad (10)$$

where P is the pressure, s the molecular cross section, and A the area the pressure acts on.

Let us keep in mind that if several objects are influenced simultaneously, then A is the total cross-sectional area of all the objects. Thus if A_{cube} is the cross-sectional area of a single cube, $A = n\, A_{cube}$, where n is the number of cubes acted on.

6. Effect of ΔP on a Tumbling Cube

Let us now evaluate the effect of ΔP on a tumbling cube. The cube travels forward by rotating on successive corners, and the action of gravity on the center of mass causes it to rotate sideways during each forward step, going to the right or left depending on whether the center of mass is to the right or left of the corner the cube is tumbling about. The motion of the cube is deterministic and depends on its initial conditions; it is assumed that the particular trajectory the cube follows depends on the initial angle of orientation of the center of mass with respect to the corner. The cube has mass M, forward velocity u and *half-length* b. The cube takes s forward steps (tumbles about a corner) in its trajectory, and the center of mass undergoes an average sideways step of length a during each tumble. The pressure ΔP of the ordered air molecules causes the cube to rotate by an angle Δq, which in turn causes the cube to follow a different trajectory than its original one and to have an average sideways deviation ΔY due to mental influence at the end of s steps.

In order to predict ΔY, we need to know the angular deviation Δq produced by ΔP. This pressure acts on a cross section A of the cube, which, because the cube is tumbling at a skew angle, is approximated by $(2b)(2b\sqrt{3})$, where b is the *half-length* of a side (i.e., the length of a side is $2b$). It is assumed that ΔP acts uniformly across this area and in a direction orthogonal to the line from the corner to the center of mass, so the torque L is equivalent to a torque acting on the center of mass. The distance from the corner to the center of mass is $b\sqrt{3}$, so $L = \Delta P\, A\; b\sqrt{3} = I\, \mathrm{d}^2(\Delta q)/\mathrm{d}t^2$, where I is the moment of inertia about a corner. Noting that $I = 4Mb^2$ (equations (7) and (8) in Burns (2002b)) and neglecting a factor $g \approx 1$), we have

$$\frac{d(\Delta q)}{dt} = \frac{3b}{M}\int_0^t dt\,\Delta P(t)\ . \tag{11}$$

We do not know how ΔP varies in time. However, we suppose that

$$\Delta P = \Delta P_0 \exp(-t/t_I) \tag{12}$$

and call t_I the time constant for mental influence. We now can evaluate equation (11), and find

$$\frac{d(\Delta q)}{dt} = \frac{3b}{M}\Delta P_0 t_I \left[1-\exp(-t/t_I)\right]. \tag{13}$$

Let us define $r = t_I / t_{cube}$. We find

$$\Delta q(t_{cube}) = \frac{3b}{M}\Delta P_0 t_{cube} t_I \left[1-r(1-e^{-1/r})\right]. \tag{14}$$

The term $t_I\,[1\text{-}r(1\text{-}e^{-1/r})]$ describes the dependence of $\Delta q\ (t_{cube})$ on t_I. The factor in brackets equals 1 when $r = 0$; it decreases thereafter, but remains near unity in the range $r \leq 1$. As has been discussed in Burns (2002b, Section 2), the action of mental influence on a traveling cube is only important during the first few steps; after that it has little effect. Therefore, the use of a time constant larger than t_{cube} would be ineffective, and we assume that r is not greater than 1. We take the log of Δq in computing ΔY, so we can set the factor in brackets to 1 with little error. We now have

$$\Delta q(t_{cube}) = \frac{3b}{M}\Delta P_0 t_I t_{cube}\ . \tag{15}$$

Evaluating t_{cube} in terms of cube parameters (equation (7)), we find[(1)]

$$\Delta q(t_{cube}) = \Delta P_0 t_I \frac{2pb^2}{Mu}\ . \tag{16}$$

Therefore, by equation (5)

$$s_0 = \log\left[\frac{Mu}{6b^2}\frac{1}{\Delta P_0 t_I}\right] / \log 2\,. \tag{17}$$

7. Value of ΔP_0 Needed to Produce an Effect Due to Mental Influence

We have calculated elsewhere (Burns, 2002b, Section 7) the value of s_0 corresponding to Forwald's (1959, 1969) experimental results. It was noted therein that because Forwald did not know of the extreme ability

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(1) If the cube were bouncing, rather than tumbling, t_{cube} would stay in the equation as an independent parameter. Also, in that case the moment of inertia about the center of mass, instead of about a corner, would be used.

of the cube to magnify initial perturbations, he took no precautions to shield against air currents from breath or hand movements which might have affected results. Therefore, even supposing that Forwald's deviation results were produced by a small pressure ΔP_0 acting at the beginning of the trajectory, we do not know whether that pressure was produced by molecules ordered by mental influence or by artifactual air currents. However, we can compute the value of ΔP_0 which corresponds to the above value of s_0 and simply note that we do not know how ΔP_0 was produced.

The cubes used in Forwald's experiments typically had M = 5 gm and b = 0.8 cm, and as discussed in Section 4 we take the initial value for the forward velocity u to be 100 cm/sec. These values would also be typical of cubes (dice) used in games of chance. The value of s_0 was estimated in Burns (2002b, Section 7) as about 29 $\pm$ 2 steps, corresponding to a distance of forward travel X_0 of 40 $\pm$ 3 cm.

We can now calculate ΔP_0. We rewrite equation (17) as

$$\Delta P_0 = \frac{Mu}{6b^2} \frac{2^{-s0}}{t_I}. \tag{18}$$

Substituting the above values we find for s_0 = 29, ΔP_0 = 2.42x10^{-7}/t_I dyne/cm^2. The range of $\pm$ 2 steps corresponds to multiplying or dividing by 2^2 = 4, so the range for ΔP_0 is 6.06x10^{-8}/t_I to 9.69x10^{-7}/t_I dyne/cm^2. As discussed in the previous section, we take $t_I \le t_{cube}$, and using equation (7) we find t_{cube} = 1.67x10^{-2} sec. Setting $t_I = t_{cube}$ gives a value for ΔP_0 of 1.45x10^{-5} dyne/cm^2, with a range of 3.62x10^{-6} to 5.79x10^{-5} dyne/cm^2.

8. The Number of Molecules Which Must Be Simultaneously Influenced to Produce ΔP

If a person simultaneously acts on n tumbling cubes, then by equations (10) and (12), we can write

$$N_I = N_{I,0} \exp(-t / t_I) \tag{19}$$

and

$$N_{I,0} = \frac{\sqrt{2p}}{20} \frac{\Delta P_0}{P s} n A_{cube}, \tag{20}$$

where A_{cube} is the cross-sectional area of a cube. Each cube is rotating at a skew angle, and its average cross-sectional area is estimated as $(2b)(2b\sqrt{3})$. Thus at atmospheric pressure $N_{I,0}$ = 4.33x10^9 $nb^2 \Delta P_0$.[(2)]

Forwald (1959, 1969) released six cubes in each experimental trial, and we assume he influenced each of them simultaneously.[(3)] Using the above value for b, we find $N_{I,0}$ = 1.662x10^{10} ΔP_0. If mental influence can act throughout the time t_{cube} for one tumble of a cube, the least amount of pressure ΔP_0 is needed to produce Forwald's results. (It would be higher if mental influence lasted for a shorter time.)

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(2) P = 1.103x10^6 dyne/cm^2; s , the average molecular cross section for air, equals 1.98x10^{-16} cm^2.

(3) It has been proposed that Forwald only influenced one cube out of the six each time (Walker, 1975). However, Forwald assumed that he affected all six cubes in computing his mean deviations, so if his values for the deviations are to be used, the same assumption must be made.

Using this minimum pressure and its corresponding range, we find the minimum number of molecules needed to produce Forwald's results is 2.41×10^5, with a range of 6.02×10^4 to 9.62×10^5.

9. Comparison with Other Effects Involving Ordered Molecules

It has been shown elsewhere (Burns, 2002a) that about 80 ordered molecules traveling at thermal energy in the brain can break an ionic or covalent chemical bond. If opening a gate to a sodium channel in the neuronal membrane requires breaking five bonds, then about 400 molecules are needed for that. Producing an action potential usually requires opening several gates, and initiating a physical action probably requires more than one action potential in the brain. If we estimate that these factors multiply the number of molecules by 10, then about 4,000 ordered molecules are needed to initiate a physical action. As was noted in Section 5, because each ordering is done via coordinate shifts along a mean free path, plus magnification of these shifts by interaction with another molecule at the end of the mean free path, twice as many molecules must be influenced as are ordered, with all of these influenced over the course of a mean free path. Therefore, 8,000 molecules must be simultaneously influenced to produce a physical action.

If mental influence acts by ordering molecules, one would expect that the number of molecules it can simultaneously influence outside the brain would be similar to, or less than, the number it can influence within it. The number of molecules calculated in the last section to affect a tumbling cube is higher than the number to produce a single action potential by a factor of 30. But mental influence may do more in the brain than produce a single action potential at a time, and in any case both numbers are rough estimates. From this perspective the numbers are reasonably compatible.

The possibility of affecting a low-noise microphone by ordered molecules has also been analyzed (Burns, 2002a). Such a microphone could detect -2.5 db, which corresponds to 1.5×10^{-4} dyne/cm^2. For a microphone area of 0.10 cm^2 about 10^4 molecules would need to be simultaneously influenced to produce the required pressure. This number is less than the minimum number of molecules necessary to explain the above results with the traveling cube, yet effects of mental influence are not detected by microphones. However, as was discussed in Burns (2002a), it may be that mental influence orders molecules in a very rough process and cannot produce a signal which varies coherently across a macroscopic surface. This lack of coherence would mean that ordered molecules could not produce a signal detectible by a microphone.

10. Dependence of s_0 on Parameters Describing Tumbling Cubes

All dependence of s_0 on individual persons is in ΔP_0 and t_I. Thus let us assume that ΔP_0 and t_I are constant for a given person, and compare effects, using cubes with different parameters. We will delineate set (1) as reference parameters. Then

$$s_0 - s_0^{(1)} = \log\left[\frac{Mu}{M_1 u_1}\frac{b_1^{\,2}}{b^2}\right]/\log 2\,. \qquad (21)$$

We note that the *difference* in values of s_0 is independent of the person acting.

If the cubes gain their velocity from tumbling down a ramp, they will have the same average velocity (assuming that differing effects of friction on cubes made of different materials are not large). In that case

$$s_0(M,b) - s_0(M_1,b_1) = \log\left[\frac{M}{M_1}\frac{b_1^{\,2}}{b^2}\right]/\log 2\,. \qquad (22)$$

As an example, suppose $M = 8m_1$ and the lighter cube is hollow and larger, with $b_1 = 2b$. Then $s - s_0^{(1)} = \log_2(8) + 2\log_2(2) = 3 + 2 = 5$.

We should note, however, that values of t_I and ΔP_0 for a given individual may vary somewhat for psychological reasons, such as mood (Broughton, 1991) and series position of experimental trials (Dunne et al., 1994), and this variation is apt to smear out a curve by several steps. However, a difference in s_0 for different parameters such as the above example may be detectible. (For details on experimental procedures using tumbling cubes, see Burns (2002b).)

11. The Use of Multiple Cubes

Let us now inquire about the effect of varying the number of cubes a person simultaneously affects. We will take $N_{I,0}$ to be a constant characteristic of the person acting (subject to psychological variation). (See Burns (2002a, Section 7) for further discussion of this point.) Then by equation (10), $\Delta P_0 A$ is a constant, where A is the total cross sectional area involved. If a person simultaneously acts on n cubes, then $A = n\,A_{cube}$, where A_{cube} is the cross-sectional area of a single cube. Therefore, ΔP_0 is proportional to n^{-1}. If we compare s_0 for n and n_1 cubes, respectively, all with the same cube parameters, we have from equation (17)

$$s_0(n) - s_0(n_1) = \log(n/n_1)/\log 2\,. \qquad (23)$$

As is the case when cube parameters are varied, the difference in s_0 is independent of the person acting.

If this relationship is tested experimentally, several factors must be kept in mind, however. For one thing, as we have seen, most of the effect of mental influence is produced in the first few steps of each cube's trajectory. Thus, even supposing that all cubes are released simultaneously, a person could influence one third, say, of the cubes on the first step, one third on the second step, and one third on the third step, without any great change in the deviation due to mental influence. If more than three cubes are used in each comparison set, this would have no effect on the comparison predicted by the above formula. However, if a large number of cubes were compared to only one or two, the difference in s_0 might not be as great as would be predicted above. It would be better to use a minimum of six cubes as a reference number to compare with larger numbers of cubes.

It is also important to release all the cubes at the same time, within as narrow limits as possible. Equation (7) tells us that for typical cube parameters (b = 0.8 cm, u = 100 cm/sec), $t_{cube} = 1.676\text{x}10^{-2}$ sec. To the extent that the total release time for all the cubes is greater than that, the person can act on cubes sequentially and substantially diminish the above difference in s_0. For instance, suppose a comparison is made of 64 (2^6) cubes and 6 ($\approx 2^{2.6}$) cubes. If all 64 cubes can be released within 10^{-2} sec of each other (and similarly the 6 cubes are released within that time frame), the above equation predicts that s_0 will change by 6.0 – 2.6 = 3.4 steps. But if it took 1.07 sec to release the 64 cubes, she could act on all of them sequentially.

12. Dependence of ΔP_0 on Pressure

The dependence of ΔP_0 produced by mental influence on pressure P could be determined experimentally by measuring the deviation of a cube tumbling within a vacuum chamber. For the same person acting on cubes of the same mass, size, and velocity, we have from equation (17)

$$s_0(P) - s_0(P_1) = \log\left[\frac{\Delta P_0(P_1)}{\Delta P_0(P)}\right]/\log 2\,, \qquad (24)$$

where P_1 is a reference pressure (atmospheric, say). If $N_{I,0}$ is a constant characteristic of the person acting, independent of pressure, then by equation (20)

$$s_0(P) - s_0(P_1) = \log(P_1 / P) / \log 2 \,. \tag{25}$$

Reduction of Effects of Mental Influence When Mean Free Path Becomes Greater Than the Dimension of the Vacuum Container. When the mean free path l becomes comparable to the size of the vacuum container, the gas molecules tend to strike the walls rather than interact with each other. Although a wall can be considered perfectly reflecting on the average, individual gas molecules will be affected by minor deviations on an atomic scale and in effect interact with several molecules in the wall each time they hit it. If $N_{I,0}$ is a constant characteristic of the person acting, then the total number of molecules which can be ordered is reduced and ΔP_0 is thereby reduced. Using the expression for l (see equation A.1 in Burns (2002a) and relevant constants), we find that for a container with dimension L of one meter, this effect takes place in air at 20°C at a pressure of 6.32×10^{-7} atmospheres (= 4.80×10^{-4} torr).

13. Summary and Discussion

This paper combines the results of two previous papers and continues the exploration of the ideas therein. First, it has earlier been shown (Burns, 2002b) that a traveling cube can magnify a very small change in initial angle of orientation to produce a sideways deviation ΔY at the end of the trajectory, according to the formula $\Delta Y = a(s\text{-}s_0)$, where a is the average sideways step length, s the number of steps in the trajectory, and s_0 the minimum number of steps necessary to produce any substantial effect. Thus mental influence could produce a deviation at the end of the trajectory by exerting a small angular change at the beginning.

The above paper did not make any assumption about the size of the angular shift, other than that it is small. However, it has also been proposed (Burns, 2002a) that mental influence acts within the limits of the uncertainty principle. The present paper incorporates this assumption and explores quantitatively two possibilities: (a) the angular shift is produced when the cube, with its macroscopic mass, is shifted within the limits of the uncertainty principle, and (b) the angular shift is produced by the impact of ordered molecules. (It has been shown by Burns (2002a) that the limits of the uncertainty principle permit ordering the direction of travel of a molecule in one mean free path.)

If the shift in initial angle were the amount permitted by the macroscopic mass of the cube, then for a cube with parameters typical of Forwald's (1959, 1969) experiments and games of chance, s_0 would equal 49 steps, corresponding to a forward distance of travel of 68 cm. But results of mental influence are reported in shorter distances than that, both in Forwald's experiments and anecdotally. It is concluded that if mental influence shifts the initial angle of the cube, it must do it some other way.

Forwald's (1959, 1969) experimental results can be explained if the pressure ΔP from ordered molecules is at least 1.45×10^{-5} dyne/cm^2, corresponding to at least 2.41×10^5 molecules simultaneously influenced.

If mental effects are produced from ordered molecules, s_0 has a logarithmic dependence on M/b^2, where M is the mass and b the half-length of the cube. If multiple cubes are affected simultaneously, s_0 will depend logarithmically on the number of cubes involved. Also, s_0 depends logarithmically on P^{-1}, where P is the ambient pressure. This logarithmic dependence on variables may explain why results in PK experiments seem to be independent of the various factors involved (Stanford, 1977).

As we have seen in sample calculations, the number of molecules which must be simultaneously influenced to account for effects of mental influence is very large. Yet persons who produce such effects have no conscious knowledge of controlling the trajectories of this large number of molecules. Also, the time during which each molecule is affected is very short (10^{-9} sec at atmospheric pressure), whereas conscious experience of time duration extends down only to a few tenths of a second. Thus if psi occurs at the molecular level, as is suggested herein, it must be carried out at a deeply unconscious level.

The latter possibility is compatible with the view that all people directly involved in an experiment -- experimenter, person assigned to produce an effect, and others -- are linked at an unconscious level, and that results due to mental influence can be due to any or all of them. (This possibility is often referred to as the *experimenter effect*.) As noted by Palmer (1997), this view is supported by a variety of experimental data. For instance, when a large group of people have intense involvement in an experience, fieldREG data show a non-random effect (Nelson et al., 1998; Radin, 1997). In a similar vein, if a number of people have a strong preference for good weather on a certain day, the microclimate in that area can be affected (Nelson, 1997).

In summary, this paper has continued an exploration of the proposal that mental influence acts by ordering quantum fluctuations within the limits of the uncertainty principle, and the finding previously made that molecules can thereby be ordered in their direction of travel in one mean free path. We have seen herein that the deviation of a traveling cube comparable to the results reported by Forwald (1959, 1969) can be accounted for by the impact of $\approx 10^5$ ordered molecules at the beginning of the trajectory, but not by a shift of the cube by the small amount permitted by the uncertainty principle for its macroscopic mass. We have seen herein that the dependence of the deviation of a traveling cube on macroscopic parameters is logarithmic, which is consistent with parapsychology experiments showing the seeming independence of PK on macroscopic variables. And we have noted herein that if mental influence acts by ordering a large number of molecules, a process individuals are quite unaware of, it must act at a deeply unconscious level.

Appendix A

Comparison of This Theory with Walker's Analysis

The context of Walker's theory is very different from that of the present theory. Walker's (1975, 1979) theory holds that consciousness collapses the quantum mechanical wave function, and that PK can act to select the most favorable branch of the wave function upon collapse, whereas the present theory holds that PK occurs as a result of ordering quantum mechanical fluctuations.

The theories are similar in that both hold that PK takes place through coordinate shifts which occur within the limits of the uncertainty principle. But because the uncertainty principle only limits the *product* of changes in coordinates, a further condition must be made in each theory to limit the change in spatial and momentum coordinates individually. Wave function collapse is presumably instantaneous, whereas in this theory root mean square changes in coordinates depend on the time elapsed (equations (2) and (3)). Walker developed his limit on the change in initial angle of a cube in an *ad hoc* intuitive way, rather than using any extensive analysis. However, as we will see below, when the variables he used to express it are transformed to the variables used herein, his expression turns out to be the same as the one used herein, to within a constant factor near unity.

According to equation (9) of the present theory, the shift $\Delta q\ (t_{cube})$ in initial angle of the cube is given by

$$\Delta q\,(t_{cube}) = \frac{1}{\sqrt{3}}\left[\frac{\hbar t_{cube}}{Mb^2}\right]^{1/2} . \qquad \text{(A.1)}$$

In Walker's expression for PK deviation of the cube, the comparable term is called dq_1. By his equation (78), neglecting factors near unity, $dq_1 = [\hbar / I w_0]^{1/2}$, where I is the moment of inertia about the center of mass, which is approximately equal to Mb^2. w_0, the angular velocity about the y axis, is called w_f in the analysis of Burns (2002b), and by equation (9) of that analysis $w_f t_{cube} = p/3$.[(4)] Therefore, $dq_1 = (3/p)^{1/2}[\hbar\, t_{cube}/Mb^2]^{1/2}$. So Walker's expression differs from that of the present theory only by a constant factor near unity. Because the log of Δq is always used in predicting the final sideways deviation of the cube, this constant factor is not important and the terms are basically identical. (Walker used the natural log, whereas this theory uses log to the base 2, but logs taken using these different bases also differ only by a constant factor near unity.)

[(4)] We are setting a factor $z \geq 1$ in that analysis.

Predictions about the traveling cube, by both Walker's theory and the present one, depend on only two things: the value of Δq, essentially the same in each theory, and the dynamical analysis of its motion. Walker's dynamical analysis was somewhat rough. For instance, he made the simplifying assumption that the distance traveled sideways is the same as the distance traveled forward during each tumble. (The analysis of Burns (2002b, Sections 3.3, 6 & 7) shows that this ratio is typically 0.25 for a tumbling cube and perhaps 0.50 for a bouncing cube.)

Both models used a set of discrete trajectories to analyze the effect of PK on the cube. Indeed, the present author took this idea from Walker's paper and found it very convenient. However, Walker's analysis of the magnifying effect of the cube trajectories was done by a different method than the present theory and was intertwined with the rest of his dynamical analysis, whereas in this theory they are done separately. For this reason, it is difficult to make any overall comparison between his analysis and the present one.

Walker concluded that Forwald's (1959) data could be accounted for by a shift in the initial angle of the cube itself. However, as we saw in Section 4 herein, the more extensive dynamical analysis of Burns (2002b) shows that the minimum distance the cube must travel in order for a sideways deviation to be produced in this way is substantially longer than the distances Forwald's cubes traveled and therefore cannot account for Forwald's results. However, Walker's work is important because he was the first to show that mental influence could be an extremely small effect which could magnified to produce macroscopic changes.

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