

# Schrödinger's cat: The rules of engagement

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28 October 2002

*In a previous paper we examined the role of a conscious observer in a typical quantum mechanical measurement. Four rules were given that were found to govern the stochastic choice and state reduction in several cases of continuous and intermittent observation. It was shown that consciousness always accompanies a state reduction leading to observation, but its presence is not sufficient to 'cause' a reduction. The distinction is clarified and codified by the rules that are repeated below. In this paper, these rules are successfully applied to two different versions of the Schrödinger cat experiment.*

## Introduction

In the previous paper [1], an interaction was studied involving a particle passing over a detector with a probability that it will either be captured, or that it will pass undetected. A conscious observer witnesses the detector at various times during the interaction.

It was found that when a conscious observer follows the evolution of the detector's state, consciousness always accompanies the state reduction associated with a measurement of the particle. During the several cases that were investigated, consciousness was found to switch from one detector state to another at on the occasion of a stochastic choice.

Four rules were proposed in the previous paper that correctly describe the expected outcome in all these cases. The first of these rules, given below, refers to the

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*probability current*  $J$  that flows into a state. The current  $J$  is defined to be the time rate of change of the square modulus.

**Rule (1):** *For any subsystem of  $n$  components in an isolated system with a square modulus equal to  $s$ , the probability per unit time of a stochastic choice of one of those components at time  $t$  is given by  $(\sum_n J_n)/s$ , where the net probability current  $J_n$  going into the  $n^{\text{th}}$  component at that time is positive.*

The *ready brain state* referred to in rule (2) is defined as one that is not conscious, but is physiologically capable of becoming conscious if it is stochastically chosen. An active brain state is one that is either conscious or ready.

**Rule (2):** *If the Hamiltonian gives rise to new components that are not classically continuous with the old components or with each other, then all active brain states that are included in the new components will be ready brain states.*

**Rule (3):** *If a component that is entangled with a ready brain state  $B$  is stochastically chosen, then  $B$  will become conscious, and all other components will be immediately reduced to zero.*

**Rule (4)** *A transition between two components is forbidden if each is an entanglement containing a ready brain state of the same observer.*

The purpose of the present paper is to apply these rules to two versions of the Schrödinger cat experiment. Version I is a somewhat modified formulation of that famous puzzle. It usually involves a cat being placed on two components of a quantum

mechanical superposition, where it is alive on one component and dead on the other. This distinction is ambiguous because an alive cat can be unconscious, in which case it is every bit as inert as a dead cat. The distinction used here is that the cat is conscious on one component of the superposition, and unconscious on the other. In version II, the cat begins in an unconscious state, and is aroused to a conscious state.

## The Apparatus

The apparatus will consist of a radioactive source and detector that will be denoted by either  $D_0$  or  $D_1$ , where the first means that the detector has not yet received a decay particle, and the second means that it has. The detector output will be connected to a mechanical device that carries out a certain task, such as a hammer falling on a container that then releases an anesthetic gas. This device will be denoted by  $M(\alpha, t)$ , where  $\alpha$  indicates the extent to which the task has been completed, and  $t$  is the time.  $D_0M(\alpha_0, t)$  means that the source has not yet decayed at time  $t$  and that the mechanical device is still in its initial position given by  $\alpha_0$ .  $D_1M(\alpha_1, t)$  means that the decay has already occurred by the time  $t$ , and that the mechanical device has advanced to a position given by  $\alpha_1$ . Let  $I_0$  be an indicator that tells us that  $M$  has not completed its task, and  $I_1$  tells us that it has. Then  $D_1M(\alpha_1, t)I_0$  means that the device has not completed its task at time  $t$ . When  $\alpha = \alpha_f$ , we will say that the device  $M$  has fully run its course, so  $D_1M(\alpha_f, t)I_1$  means that the source has decayed, and that the mechanical device has completed its task at time  $t$  as indicated by  $\alpha_f$  and by the indicator  $I_1$ . We also suppose that the source is exposed to the detector for a time that is limited to the half-life of a single emission. At that time a clock will shut off the detector, so it will remain in the state  $D_0$  if there has not yet been a particle capture.

The system at  $t_0 = 0$  is then:  $\Phi(t_0) = D_0M(\alpha_0, t_0)I_0$ , and in time it becomes

$$\Phi(t = t_0) = D_0M(\alpha_0, t)I_0 + \int dz D_1M(\alpha_z, t)I_0 + D_1M(\alpha_f, t)I_1 \quad (1)$$

where  $\int dz D_1M(\alpha_z, t)I_0$  and  $D_1M(\alpha_f, t)I_1$  are zero at  $t_0$ , and  $z$  covers the range  $0 = z < f$ .

The significance of the integral is that at some time  $t$  there is a spread of alphas that represent the possible state of the mechanical device at that moment. Although the device is a classical object, there is a quantum mechanical uncertainty as to when it begins its operation. The function  $M(\alpha_z, t)$  is therefore a pulse that represents that uncertainty moving along the  $+z$  axis. As time progresses, the second component in eq. 1 and then the third component will gain in amplitude, but the third component cannot do that until after a time  $T$  that corresponds to the time it takes for the mechanical device to complete its task.

Since we arranged to have the first component decrease for a time equal to the half-life of a single emission, its square modulus will stabilize to a constant value of 0.5 at that time, assuming that eq. 1 is normalized. After that, no new current will flow into the second component, so its amplitude will fall back to zero as the pulse in  $M(\alpha_z, t)$  runs out along  $+z$ . When  $M(\alpha_z, t)$  finally goes to zero, the third component will reach its maximum value. In the end, the first and third components will survive, each with a square modulus equal to 0.5.

## Sequential Interactions with an Observer

This apparatus involves two sequential interactions: the radioactive decay and the operation of the mechanical device. The previous paper (ref. 1) did not consider more than one interaction, so before inflicting this apparatus on a cat, we will see how the rules work when an outside observer witnesses the apparatus in operation.

Let the external observer look at the apparatus at some time  $t_{ob}$  after the process has begun. Equation 1 will then become

$$\begin{aligned} \Phi(t = t_{ob}) = & D_0 M(\alpha_0, t) I_0 X + \int dz D_1 M(\alpha_z, t) I_0 X + D_1 M(\alpha_f, t) I_1 X \\ & + D_0 M'(\alpha_0, t) I_0 B_0 + \int dz D_1 M'(\alpha_z, t) I_0 B_1 + D_1 M'(\alpha_f, t) I_1 B_1 \end{aligned} \quad (2)$$

where  $X$  is the unknown brain state of the observer prior to the observation, and  $B_0$  and  $B_1$  are normalized ready brain states of the observer that perceive  $D_0$  and  $D_1$  respectively. The three ready brain components are zero at  $t_{ob}$ , and thereafter receive current from the corresponding component in the first row of eq. 2. That current is due to the physiological interaction that occurs when the observer interacts (e.g., visually) with the apparatus.

Rule (1) with  $n = 3$  (treating the integral as one component) requires that the time integrated current flowing into the second row of eq. 2 must equal 1.0. So one or the other component must be eventually chosen. We take them in reverse order.

If the observation occurs after time  $T$ , current will have flowed into the last component  $D_1 M'(\alpha_f, t) I_1 B_1$  of eq. 2. If that component happens to be stochastically chosen at a time  $t_{scf}$ , then the ready state  $B_1$  will become conscious, and following rule (3),

$$\Phi(t = t_{scf} > t_{ob}) = D_1 M(\alpha_f) I_1 \underline{B}_1$$

This will complete the interaction. It corresponds to the observer coming on the scene when the mechanical device has already finished its task. As in the previous paper, underlining a brain state such as  $\underline{B}_1$  means that it is a conscious state.

The fifth component in eq. 2 containing the integral is a continuum of components in the variable  $\alpha_z$  at time  $t$ . If one of those components is stochastically chosen at a time  $t_{sc1}$ , the corresponding value  $\alpha_{sc1}$  will be selected at that time. That choice will make  $B_1$  conscious, and following rule (3), the system will become

$$\Phi(t = t_{sc1} > t_{ob}) = D_1 M(\alpha_{sc1}) I_0 \underline{B}_1 \quad (3)$$

From this point on the observer will track the behavior of the mechanical device like a classical observer. The Hamiltonian will carry the mechanical device through its paces from  $\alpha_{sc1}$  to  $\alpha_f$  while the conscious observer  $\underline{B}_1$  remains focused on the detector state  $D_1$ .

Another possibility is that there will be a stochastic choice of the fourth component in eq. 2 at a time  $t_{sc0}$ . According to rule (1), this can only happen while that component is still increasing; and that can only happen before the radioactive source has reached the single emission half-life time  $t_{1/2}$ , inasmuch as the detector is cut off at that time. Assuming that this time has not run out, and that the fourth component is stochastically chosen, then  $B_0$  will become conscious, giving

$$\Phi(t_{1/2} > t = t_{sc0} > t_{ob}) = D_0 M(\alpha_0) I_0 \underline{B}_0$$

This corresponds to the outside observer coming upon the apparatus *before* the radioactive source has decayed. The system will then continue to evolve, starting at the new time,

$$\Phi(t_{1/2} > t = t_{sc0} > t_{ob}) = D_0 M(\alpha_0, t) I_0 \underline{B}_0 + D_1 M''(\alpha_0, t) I_0 B_1 \quad (4)$$

where  $D_1 M''(\alpha_0, t) I_0 B_1$  is zero at  $t_{sc0}$ . This component will not take the form of an integral over  $\alpha_z$  because the Hamiltonian will only connect the first component with the second component in eq. 4; and in addition, rule (4) will not allow a self-generating succession of ready brain states. That is, a transition to a component  $\alpha_z$  containing a ready brain state  $B_1$  is not allowed if it can only come from another component  $\alpha_z'$  containing the ready brain state  $B_1$ . Consequently, the component  $\alpha_0$  cannot be skipped over as the mechanical device begins its operation. The significance of this is discussed in the last paragraph of this section.

If the second component in eq. 4 is stochastically chosen at time  $t_{sc1}'$  such that  $t_{1/2} > t_{sc1}' > t_{sc0}$ , then the system will again be reduced, giving

$$\Phi(t_{1/2} > t = t_{sc1}' > t_{sc0} > t_{ob}) = D_1 M(\alpha_0) I_0 \underline{B}_1$$

From this point on, the observer will track the classical behavior of the mechanical device as happened following eq. 3. In this case it begins with  $\alpha_0$ .

And finally, if the fourth component of eq. 2 is stochastically chosen but the second component of eq. 4 is *not* chosen, then the first component (of eq. 4) will run out the half-life time on the clock, rendering its output current equal to zero. When that happens eq. 4 will stabilize to give

$$\Phi(t = t_{1/2}) = D_0 M(\alpha_0) I_0 \underline{B}_0 + D_1 M''(\alpha_0) I_0 B_1 \quad (5)$$

where each component has come to the same constant square modulus. The continuing existence of this *residual superposition* is not unphysical. It is like similar cases in the previous paper (ref. 1) where the conscious observer on one component is unaware of the other (not conscious) component. It was shown in that paper that the rules require another reduction if a second observer looks in on the scene in eq. 5, or if the conscious attention of the primary observer is allowed to drift in any way. This reduction will

eliminate the second component in eq. 5. We call this a "phantom" component because it serves no further purpose at this point. Equation 5 therefore corresponds to the observer finding the detector in the state  $D_0$  with the clock run out.

The clock limiting the detector is set to equal the half-life of a single emission, and this means that there is a 50% chance that the system will be given by eq. 5. That will happen if a stochastic choice of the fourth component of eq. 2 is chosen at time  $t_{sc0}$ ; and if subsequently, the stochastic choice of the second component in eq. 4 is not chosen at time  $t_{sc1}$ . Otherwise, there is a 50% chance that the outside observer will witness the mechanical device complete its operation to the end.

It should be noted that rule (4) saves us from another anomaly that is different in kind from the one noted in the previous paper. If the second component of eq. 4 were an integral over  $\alpha_z$ , eq. 5 would never be able to stabilize as a residual superposition. That's because a pulse of ready brain states would then run through the second component, and its leading edge would be continuously receiving current from the trailing edge. The pulse is not normalized, but since it keeps using the same current over and over again, rule (1) guarantees that there will be an eventual stochastic hit on a ready brain component within the pulse. That guarantees a reduction in which the first component in eq. 5 would become zero. This is an anomalous result because it would prevent the observer from ever finding the detector in the state  $D_0$  with the clock run out.

## Version I

We now replace the indicator in eq. 1 with a cat that is initially in the conscious state  $\underline{C}_0$  as shown in the first component of eq. 6. The mechanical devise is one that will render the cat unconscious, as represented by the state  $U$  in the last component of eq. 6. As in the previous paper, we require that the lower physiological functions leading to  $U$

are included in the variable  $\alpha$  of the mechanical device, just prior to its reaching  $\alpha_f$ . This means that the mechanical device in eq. 6 is different to this extent from the device in eq. 1. Before a stochastic choice occurs, the system would then *apparently* be given by

$$\Phi(t = t_0) = D_0M(\alpha_0, t)\underline{C}_0 + \int dz D_1M(\alpha_z, t)C_1 + D_1M(\alpha_f, t)U \quad (6)$$

where the last two components are initially equal to zero. However, the conditions of the experiment require that the cat is still conscious when the mechanical device begins its operation at  $\alpha_0$ ; so  $\alpha$  in the second component in eq. 6 must have a sub-zero value when that component becomes active. Here again,  $\alpha_0$  cannot be skipped over. This means that the last component and all but the first component of the integral are not really present in eq. 6 since they cannot possibly appear before there has been a stochastic choice. This requirement is enforced by rule (4) that again forbids a self-generated integral of ready brain states. Equation 6 should therefore be written

$$\Phi(t = t_0) = D_0M(\alpha_0, t)\underline{C}_0 + D_1M'(\alpha_0, t)C_1 \quad (7)$$

where  $D_1M'(\alpha_0, t)C_1$  is zero at  $t_0$ . If this component is stochastically chosen at time  $t_{sc}$ , then the system will be

$$\Phi(t_{sc}) = D_1M(\alpha_0)\underline{C}_1 \quad (8)$$

From this point on, the cat will track the classical behavior of the mechanical device until it completes the task of rendering the creature unconscious at time  $t_f$ . The final state of the cat is then given by

$$\Phi(t = t_f) = D_1M(\alpha_f)U \quad (9)$$

If, on the other hand, the second component in eq. 7 is not stochastically chosen, then the components will stop interacting at the half-life time  $t_{1/2}$ , so current will cease flowing from the first to the second component in that equation. This means that eq. 7 will stabilize in place giving

$$\Phi(t = t_{1/2}) = D_0 M(\alpha_0) \underline{C}_0 + D_1 M'(\alpha_0) C_1 \quad (10)$$

where both components have come to a square modulus equal to 0.5, assuming that eq. 7 is initially normalized. As in eq. 5, the cat will be conscious without any awareness of the other component, so the phantom component of this residual superposition does no harm.

There is a 50% possibility that eq. 9 will be the final state, and a 50% possibility that eq. 10 will be the final state. This outcome conforms to normal expectations, so rules (1) - (4) are adequate to the task.

## Paradox Lost

Equation 10 shows a conscious cat on one component of the superposition with a square modulus equal to 0.5, and a non-conscious cat on the other component with the same square modulus. This is a form that is generally said to be paradoxical. How, it is asked, can the cat have the same 'intrinsic' probability of being both conscious and non-conscious at the same time? The question suggests that the cat's state is truly enigmatic. But that is not so.

In the first place, it is not correct in this treatment to say that either component has an 'intrinsic' probability of any kind. Probability is associated only with current flow, not with the magnitude of a square modulus. There is no current flow in eq. 10. Second, the cat is unambiguously conscious in this superposition. The cat would certainly say so, and so would an outside observer for whom the second component is only a phantom. There is therefore nothing paradoxical about eq. 10.

## Version I with Outside Observer

Imagine that an outside observer looks in on the cat *during* these proceedings to see how it is doing. If that happens after the cat has engaged the mechanical device in the classical progression following eq. 8, then the observer and the cat will together follow the classical working out of the mechanical device.

If the outside observer interacts with the system before a stochastic choice causes the cat to become classically engaged, then eq. 7 becomes

$$\begin{aligned} \Phi(t = t_{ob} > t_o) = & D_0 M(\alpha_0, t) \underline{C}_0 X + D_1 M'(\alpha_0, t) C_1 X \\ & + D_0 M''(\alpha_0, t) \underline{C}_0 B_0 \end{aligned} \quad (11)$$

where the third component is equal to zero at  $t_{ob}$ . A fourth component is forbidden by rule (4).

If the second component of eq. 11 is stochastically chosen, the result will be the same as eq. 8 with the outside observer still “outside”. This corresponds to the case in which the mechanical device begins its operation after the observation but before the second observer can (physiologically) come on board. Of course, he will be on board as soon as his physiological processes permit, and from that point on he will follow the classical evolution of the cat.

If the third component in eq. 11 is selected at time  $t_{sc0}$ , this will correspond to the conscious observer joining the conscious cat before the mechanical interaction has begun. The result would be  $D_0 M(\alpha_0) \underline{C}_0 \underline{B}_0$ , and its continuing evolution would yield

$$\Phi(t = t_{sc0}) = D_0 M(\alpha_0, t) \underline{C}_0 \underline{B}_0 + D_1 M''(\alpha_0, t) C_1 B_1$$

where the second component is equal to zero at  $t = t_{sc0}$ . This is the same as eq. 7, except that the second observer is now on board with the cat and will follow its classical fate in eqs. 8 and 9, or join it in the residual superposition of eq. 10.

The total probability is found from rule (1) with  $n = 2$  involving the integrals of current into the second and third components of eq. 11, that are taken from  $t_0$  to the end of both the mechanical and physiological interactions.

$$\int dt [J_x + J_0] = 1$$

where  $J_x$  and  $J_0$  go into  $D_1M'(\alpha_0, t)C_1X$ , and  $D_0M''(\alpha_0, t)\underline{C}_0B_0$ . So if the second component of (a normalized) eq. 11 is not stochastically chosen, it is certain that the third component will be chosen.

## Version II

In the second version of the Schrödinger cat experiment, the cat is initially unconscious, and is awakened by an alarm that is set off by the capture of a radioactive decay particle. The mechanical device  $M(\alpha, t)$  is now an alarm clock, where  $\alpha$  represents the successive stages that progress from the initial ring to the low level physiological processes that terminate in the cat's ready brain state. As before, the alarm will only go off 50% of the time.

$$\Phi(t = t_0) = D_0M(\alpha_0, t)U + \int dz D_1M(\alpha_z, t)U + D_1M(\alpha_f, t)C \quad (12)$$

where  $U$  is the unconscious state of the cat,  $C$  is the cat's ready brain state, and the second and third components are initially equal to zero. Variable  $z$  covers the range  $0 = z < f$ . Again, there may be a time delay  $T$  before the third component containing the ready brain state of the cat can accumulate value after  $t_0$ . We assume eq. 12 to be normalized.

When current does flow into the third component it might be stochastically chosen at time  $t_{sc}$ . If that happens, then the system will become

$$\Phi(t = t_{sc}) = D_1M(\alpha_f)\underline{C} \quad (13)$$

This will terminate the interaction. It corresponds to the cat finding himself aroused by the alarm, and this will happen 50 % of the time.

Only the third component in eq. 12 contains a ready brain state, so only it can be stochastically chosen in a way that leads to a rule (3) reduction. If there is no stochastic choice, then the square modulus of the first component of eq. 12 will fall to a value of 0.5. The second component will initially rise to some positive value and fall again to zero, and the third component will rise to a square modulus of 0.5. In the final state of the system, the square moduli of the first and third components will be equal to 0.5, and the second component will be zero. Therefore, some time  $t_f$  after the alarm mechanism has run its course, the system will end its evolution in the superposition

$$\Phi(t > t_f) = D_0M(\alpha_0)U + D_1M(\alpha_f)C \quad (14)$$

which will appear 50% of the time. This superposition will only be reduced if there is an outside observer, or if the cat wakes up naturally. We will take these two cases separately

## Version II with Outside Observer

If the outside observer makes contact with the cat & apparatus after there has been a stochastic choice leading to eq. 13, then following a separate physiological interaction, the conscious observer will be on board with the conscious cat. The two of them will then experience an amended version of eq. 13 given by

$$\Phi(t = t_{sc}) = D_1M(\alpha_f)\underline{CB}_1 \quad (15)$$

where  $\underline{B}_1$  is the conscious state of the outside observer.

Now imagine that the outside observer enters the picture before the stochastic choice that leads to eq. 13. Equation 12 would then become

$$\begin{aligned} \Phi(t_{sc} > t = t_{ob}) = & D_0M(\alpha_0, t)UX + \int dz D_1M(\alpha_z, t)UX + D_1M(\alpha_f, t)CX \quad (16) \\ & + D_0M'(\alpha_0, t)UB_0 + \int dz D_1M'(\alpha_z, t)UB_1 \end{aligned}$$

where the primed components in the second row are equal to zero at  $t_{ob}$ . A sixth component is not allowed by rule (4).

If the third component in eq. 16 is stochastically chosen, realizing the component  $D_1M(\alpha_f, t)CX$ , then the continuing physiological interaction will bring about a transition from  $X$  to  $B_1$ , which will result in a final state  $D_1M(\alpha_f)CB_1$  like eq. 15. This corresponds to the cat becoming conscious after the observation but before the observer has had time to climb on board.

If  $M(\alpha_{sc1})$  within the fifth component in eq. 16 is stochastically chosen at the time  $t_{sc1}$ , this will result in the state  $D_1M(\alpha_{sc1})UB_1$ . The outside observer will then be on board with the unconscious cat when the mechanical device has reached the stage given by  $\alpha_{sc1}$ . From that point on, the observer will track the classical operation of the alarm prior to its awakening the cat. This, in turn, leads to a final state that also adds to eq. 15.

If the fourth component in eq. 16 is stochastically chosen at time  $t_{sc0}$ , then we will have the state  $D_0M(\alpha_0)UB_0$ . This will happen if the observer intervenes prior to the time that a radioactive particle is captured by the detector. In that case, the decay interaction will begin again giving

$$\Phi(t_{1/2} > t = t_{sc0} > t_{ob}) = D_0M(\alpha_0, t)UB_0 + D_1M''(\alpha_0, t)UB_1 \quad (17)$$

where the second component is zero at time  $t_{sc0}$ . Rule (4) forbids the second component from generating ready brain components that are successors to  $\alpha_0$ , so the only transition that is possible from the first component is one going to the  $\alpha_0$  component. Again,  $\alpha_0$  cannot be passed over.

If there is a subsequent stochastic choice at time  $t_{sc1}'$ , then the state in eq. 17 will become  $D_1M(\alpha_0)UB_1$ , and the observer will classically track the slumbering cat from the time the alarm mechanism is first launched to the end. This too will lead to a final state that adds to eq. 15.

The final possibility is that there will be no stochastic choice at  $t_{sc1}'$ , in which case the first term in eq. 17 will stabilize at the half-life time  $t_{1/2}$ . When that happens, we will have

$$\Phi(t > t_{1/2}) = D_0M(\alpha_0)UB_0 + D_1M''(\alpha_0)UB_1 \quad (18)$$

where the square modulus of each of the components is equal to 0.5. As in previous cases, the residual superposition in eq. 18 will be reduced if the outside observer's consciousness drifts away from  $B_0$ , or if another outside observer looks in on the experiment. Since the second component is a phantom, eq. 18 corresponds to the observer finding the cat unconscious when the clock has run out. This happens 50 % of the time, and eq. 15 happens 50 % of the time.

## Version II with a Natural Wake-Up

Even if the alarm does not go off, the cat will wake up naturally by virtue of its own internal alarm clock. The internal alarm can be represented by a classical mechanical device that operates during the same time as the external alarm. The interaction is assumed to run parallel to eq. 12, and is given by

$$\int dz N(\beta_z, t)U + N(\beta_f, t)C_N$$

where  $N(\beta)$  is the internal mechanism in the variable  $\beta$ , and  $\beta_f$  is the final value that accompanies the associated ready body state  $C_N$  of the cat. The integral covers the range  $0 = z < f$ , where  $\beta_0$  is the initial value of  $\beta$ . As with the external alarm, the internal mechanism takes a time  $T_N$  to complete its task, so  $N(\beta_f, t)C_N$  will follow from

$\int dz N(\beta_z, t)U$  only after that time has elapsed. Because it is classical, the  $z$ -wave running through the integral will be very sharply defined.

When the experiment begins, both the internal and external mechanisms will run parallel to one another, starting at the same time  $t_0$ .

$$\begin{aligned} \Phi(t = t_0) = & D_0 M(\alpha_0, t) \left\{ \int dz N(\beta_z, t)U + N(\beta_f, t)C_N \right\} \\ & + \left\{ \int dz D_1 M(\alpha_z', t) \right\} \left\{ \int dz N(\beta_z, t)U + N(\beta_f, t)C_N \right\} \\ & + D_1 M(\alpha_f, t) \left\{ \int dz N(\beta_z, t)UC \right\} \end{aligned} \quad (19)$$

where  $0 = z, z' < f$ , the first component  $D_0 M(\alpha_0, t) \int dz N(\beta_z, t)U$  is normalized to 1.0 at  $t_0$ , and all of the other components are initially zero. As before,  $C$  represents the ready body state of the cat that can be aroused by the external alarm. The sixth component in eq. 19 does not exist because  $\alpha_f$  and  $\beta_f$  are contradictory body states, so they are not permitted to emerge in a single component.

As the system evolves after  $t_0$ , probability current will flow into the components containing  $C_N$  and  $C$ , creating the possibility that one of them will be stochastically chosen. Since both are terminal states that arise from a single initial state, rule (1) requires that the probability that one of them is chosen in time  $dt$  is equal to  $(J_{C_N} + J_C)dt$ . Integrating this from  $t_0$  to the end of both interactions at time  $t_{ff}$  gives a total probability of 1.0 that one of the body states will be stochastically chosen.

We stipulated in eq. 14 that the cat was not awakened by the external alarm, even after the middle component in that equation had fallen off to zero. Applying this condition to eq. 19 gives

$$\begin{aligned} \Phi(t = t_0) = & D_0 M(\alpha_0, t) \left\{ \int dz N(\beta_z, t)U + N(\beta_f, t)C_N \right\} \\ & + D_1 M(\alpha_f, t) \int dz N(\beta_z, t)UC \end{aligned} \quad (20)$$

Under these circumstances, the probability of a stochastic choice of either  $C$  or  $C_N$  would be 0.5. Since we stated as a condition that  $C$  is not chosen, it is certain that  $C_N$  will be chosen by the time both interactions are complete. When that happens, eq. 20 becomes

$$\Phi(t > t_{ff}) = D_0 M(\alpha_0) N(\beta_f) \underline{C}_N$$

This corresponds to the cat waking up naturally to find that the detector has not captured a radioactive particle, and that the mechanical device is still in its initial  $\alpha_0$  position. Therefore, the sleeping cat's internal alarm clock does the job that the external alarm has failed to do. When we dropped the second row in eq. 19, we exclude the possibility that the cat would wake up during the operation of the mechanical device.

## References

1. R. Mould, "Consciousness: The rules of engagement", [quant-ph/0206064](https://arxiv.org/abs/quant-ph/0206064)