Theoretical Quantum Immortality and its Mathematical Authority

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Abstract. Quantum Immortality usually refers to, in a classical sense, a person who is “lucky” enough to survive in any incident in the world. Such a quantity of luckiness is even big enough to keep that person away from the aging of the human body. That is, in fact, when we say that one becomes “immortal”. Throughout the history of the world, there have been many times when people tried to find out the secret of anti-aging, but this ambitious dream, obviously, has failed every time. This paper will discuss quantum immortality in theoretical and mathematical aspects and evaluate its authority, or possibility, of its existence in real life. In order to accomplish this evaluation, the concepts of the main two interpretations of quantum physics: 1) Copenhagen Interpretation (or non-MWI interpretation), and 2) Many Worlds Interpretation (or MWI) will be necessarily involved. Throughout this paper, the MWI is proven to support the theoretical quantum immortal state, which, in this paper, means to achieve an expected theoretical outcome in the Everett box experiment. In order to show how MWI will give its credit to quantum immortality, the idea of the Infinite Monkey experiment is demonstrated in detail. After that, discussions of the computable probability of the outcome of the Infinite Monkey theorem and its pathological distribution are involved. Regardless of the situation in the Everett box, whether it is pathologically distributed or not, the mathematical outcomes show that MWI will be the only possibility of achieving the quantum immortal state during the Everett box experiment, or quantum gun experiment. Finally, the paper brings out the evaluation of quantum immortality in a real life stance.

1. Introduction
When thinking that one is “lucky” enough to survive an accident, it ultimately has to turn to the topic of possibility. The possibility of surviving after a suicide, accident, or any event that may threaten a person’s life, varies according to the details in which that person experiences throughout (or before) the event. For example, when a person is hit by a truck, he may survive if only his rib bones are broken. Now, suppose that the person’s heart, instead of ribs, is struck with the exact same force by the truck. He will then unfortunately die by experiencing this deadly impact. These determinant factors that cause all different kinds of possibilities are initially affected by all the details of that event. In another case, that person may survive simply with a book tucked in his jacket, reducing the pressure under the strike. These detail variables mentioned above are not included in idealized circumstances which we will talk about later in the paper, but it is necessary to understand how the two interpretations of quantum physics work and how it sparks their differences.
Firstly, given the Copenhagen interpretation (here we will say non-MWI), the wave function collapses into one of the multiple states of superpositions, and the square of the wave function determines the relative probability of each state and gives us the possibility of each outcome. However, there is only
one world, then followed by nothing else but one outcome of the event. While the other interpretation, the Many Worlds interpretation, known as MWI, tells that there are infinite worlds corresponding to each possible outcome of one single event. That is, those infinite worlds all exist, each representing the outcomes of that event, after that single event happens. Note that the future of all those infinite worlds will also turn to be different since the results of the possibility are all different. The main difference between non-MWI and MWI we need to know in this paper is that non-MWI has only one outcome, while MWI shows that each possible outcome turns into one corresponding world. In other words, non-MWI turns only one possibility into reality, while MWI realizes every one of these possibilities into parallel, different worlds.

In this paper, the difference of the two interpretations is made by using the Everett box experiment [1]. Everett box is a device in an idealized circumstance in which the device is separated from the rest of the universe. There are many ways of demonstrating the Everett box experiment, and in this paper, there is no requirement for any detail that exists in the real world. Therefore, Decoherence, the cause of the collapse of the wave function by that experiment’s surrounding environment, for example an air molecule, [2] will not happen in Everett box and is therefore ignored in this paper. By first understanding how the possibilities distributed differently in MWI and non-MWI interpretations, we will see that MWI always holds for at least one reality of the person who stays in a quantum immortal state, while in non-MWI it varies. According to the basic knowledge of the two interpretations and the idea of quantum immortal state, we assume that MWI will be a better supporter of the authority of quantum immortality. The Infinite Monkey experiment will then help to make any further statement into what is expected in those interpretations, in a more detailed and mathematical way. Giving then the computable pathological distribution of possibility, we will find that Everett’s conclusion may not even be fulfilled in that case. However, the supporting identity of the immortal state presented by MWI will still hold its meaning even with the exceptional conditions given by the pathological distribution. Going through our conclusion drawn by the MWI will help us understand not only the authority of the two interpretations in a computable sense, but also the authority of the possibility of quantum immortality in our real world.

2. Everett box and Quantum immortal state
Everett box is a device that holds two objects--a person (the observer) and a quantum apparatus. The person and the apparatus are inside the box, completely isolated from the universe. [3] In such idealized circumstances, the observer cannot change any aspect or detail of the quantum apparatus, waiting for its next action. The start of the experiment is simply the apparatus following an instruction--each time it either kills the person or does nothing to that person. Trial is the name given to the measurement of the action done each time by the apparatus. Each trial is done in the same period of fixed time, and the number of the trial indicates the number of actions done by the apparatus. If that person dies during the experiment, the experiment ends since any future action done by the apparatus will not change anything about that person who is already dead. With that said, however, the time still keeps elapsing, in both MWI and non-MWI. The quantum gun experiment [4] is a similar experiment but demonstrates the apparatus as a form of gun, giving the same result as Everett box does.

In such an experiment like the Everett box, the possibility of death in each trial is 50%. This means that in each trial, a person has half the chance to survive, or die. Therefore, each time an additional trial is made, the possibility of the survival of that person will decrease. In any non- MWI interpretation, if that person dies in the first trial, the experiment will end immediately and any other additional trial will be meaningless. On the other hand, the Many World Interpretation will bring significant different results. Each time a trial is finished, the result of that experiment will turn into two different worlds--both that person lives and that person dies. Note that there are no other detailed results. Such as that person dying by facing to the ground or by lying to the ground on his back. That is, since it is an idealized situation, there are only two results from such an experiment in MWI. Now what is the number of the worlds if two trials are made? In MWI, instead of the twos, now there are
four worlds in all. The alive-person world after the second trial will result in two worlds again: an alive world and a dead world. The dead person in the first trial will still split into two worlds, one remains dead and one gets killed “again”, and the third trial will be so again, shown in Figure 1. Now what we can see as the trials go on in MWI is that for Everett box in MWI, there is always one guaranteed-world in which the person is alive no matter how many trials are made in the experiment. In non-MWI, it’s not possible to always remain alive since each time the chance of surviving becomes smaller and smaller. Understanding this, it may be asserted that the MWI fulfills the expectation of being at least one immortal state, which is to not die, for that person.

![Figure 1. The results of two trials in MWI universe](image)

But does it mean that MWI is a better explanation than non-MWI overall? Let’s do some calculations. Now we know that each time a trial is made, the chance of survival of that person will decrease. We can write it into the formula of that person’s possibility of death, $D(k)$, in $k$ numbers of trial as:

$$D(k) = 1 - \left(\frac{1}{2}\right)^k$$

In which as $k$ tends into infinity, the chance of death will tend to be 1. From this, we can say, or at least assume, that MWI is a better explanation than non-MWI explanation, since MWI always guarantees one survival while in non-MWI the observer may even die in the first trial of the experiment(for that 50% chance of death). Despite what is shown above, the direct proof will not be entirely unequivocal until we bring more knowledge into this paper in a deeper, mathematical way.

3. Possibility and Infinite Monkey Theorem

3.1. Infinite Monkey and Possibility

The infinite monkey theorem is a system with a set of $m$ monkeys. In this case, $m$ is infinite, meaning that there are infinite monkeys in this universe, called the monkeyverse. [5] A typewriter is given to each monkey and each time every monkey types a letter randomly and continues this process for a period of time, which could be either finite or infinite. The monkeys’ task, what typically is described, is to successfully type the full version of the works of Shakespeare, without getting wrong for even a single letter. [6]

This may sound really humorous and ridiculous at first. But instead of imagining a group of monkeys doing something droll, let’s just consider those monkeys as devices that can produce sequences of letters of arbitrary fixed length at a fixed speed. [5] Now suppose that one of these monkeys types the word banana, which has six strings of characters. Given an alphabet $A$, in this case, $\{a,b,n\}$, (so that
would be the number 3 representing the three letters in the alphabet), the task for the monkey will be to type a $6 -$ string sequence. When typing Shakespeare’s works, instead of banana, the string character length will be $w \in \mathbb{N}$ in a $w -$ string typing task.

Giving these conditions, with $m$ monkeys we have this theorem:

**Theorem 1.** Given a finite number of $w$, an infinite number of $m$, there exists at least one monkey in the monkeyverse producing a perfect version of $w -$ string in a finite amount of time.

Proof. Giving the alphabet $A$, we can say that each time the possibility for a monkey to type one correct character is

$$\frac{1}{A}$$

(2)

Therefore, for $w$ times, the probability of a monkey typing $w -$ string, or the whole works of Shakespeare correctly is

$$\left(\frac{1}{A}\right)^w$$

(3)

Having this, we can easily have the probability which each monkey fails to produce the goal is

$$1 - \left(\frac{1}{A}\right)^w$$

(4)

Since there are $m$ monkeys in the monkeyverse, the possibility for every monkey to fail the goal, $F(m)$, is

$$F(m) = (1 - \left(\frac{1}{A}\right)^w)^m$$

(5)

Thus, as $m$ goes to infinity, $F(m)$ goes to 0, and the possibility that at least one monkey produces the correct character, $P(m)$, is

$$P(m) = 1 - F(m)$$

(6)

As as $m$ goes to infinity, $P(m)$ tends to 1.

Theorem proved.

$$\lim_{m \to \infty} P(m) = 1$$

(7)

Now it is known the result of what these hilarious human-like creatures can bring to us in the experiment. Note that this theorem does not work in real-world experiments since: the time that elapses before we have a 50% chance of finding a monkey that has typed “banana” correctly is outside the precision of typical computing software. [5]

Since now we have this theorem by assuring at least one success out of infinite possibilities, one may say that, instead of just one, however, there should be more than one success of survival in the MWI version of the Everett box experiment after an infinite number of trials. Going toward this idea, we will not only find out whether this statement is true, but also consider this idea into an even finite number of trials.

### 3.2. The Infinite Monkey Theorem

After proving theorem 1, we know that giving infinite possibilities, there would be at least one outcome that is successful. When talking about infinity, however, the main difference between Infinite Monkey and Everett box experiment in MWI is that in MWI, the start of the first trial has only one
world, instead of infinity. Each time a trial is done, the number of the worlds that exist increases exponentially. However, in the infinite Monkey experiment, the experiment simply starts with an infinite quantity of monkeys. We can only compare the two experiments when the quantity of time both goes to infinity, therefore it is not plausible to bring Theorem 1’s conclusion directly into MWI in Everett box.

Now let’s turn our view into the number of trials. Can we state which interpretation would work if it gives a fixed number of trials, instead of infinity, in the Everett box? The answer is that it may not work, classically, in such condition. Suppose an observer survives for many trials. After k number of trials, that person is not able to decide whether he lives in MWI or non-MWI worlds. In calculations, this is straightforwardly shown. the possibility of living in the alive-guarantee world L(k) is

$$L(k) = 1/(2^k)$$  \hspace{1cm} (8)

Similarly, in non-MWI world, the possibility is

$$L(k) = (\frac{1}{2})^k$$  \hspace{1cm} (9)

As shown above, the observer cannot tell which interpretation he lives in since both possibilities are equal to each other no matter how big k is. Another reason for not considering this situation is simply that the chance of surviving after k trials is just too small. Knowing this, however, the Infinite Monkey theorem (IMT) offers a whole different view in relation to the finite m monkeys in an infinite number of M monkeys.

The Theorem 2 [5] will be based on the same condition stated in Theorem 1, this time with m representing any natural number to be the first m − troop of M monkeys, in which M is infinite.

**Theorem 2 (Infinite Monkey Theorem).** Given a finite target w-string Tw and a positive real number ε, there exists a computable probability distribution on M of producing w-strings such that:

(i) the classical probability that no monkey in M produces Tw is 0;

(ii) the probability of a monkey in any m-troop producing Tw is less than ε.

And (ii) is proven by the equation [5]

$$P(m) = 1 - \prod_{k=m}^{\infty} p_k < \epsilon$$  \hspace{1cm} (10)

in which pk is the probability that the kth monkey has not produced Tw.

(ii) tells us that, according to recursive mathematics [7], the chance of finding the monkey that successfully produces the work is arbitrarily small, creating the pathological distribution situation that only depends on ε. From here, we bring our topic of how the pathological distribution affects the chances of being alive in a finite number of trials and its applicability to the two interpretations of quantum physics.

4. Pathological distribution

By giving the correspondence of each value pk and P(m) of MIT and PIT which we will talk about right below, [3] gives us a more persuasive way of stating Theorem 2 that can turn us back to our initial purpose—that is, the achievement of quantum immortal state. The IMT (Theorem 2) (ii) shows how the possibility of locating the successful monkey is arbitrarily small, even without the knowledge of m being finite or infinite. Note that this chance is only fulfilled in the condition of existing infinite monkeys in the first place, and in MWI in Everett box, two premises are needed in order to fulfill the situation of (ii) in IMT. First, it needs a possibility of a continuous finite pattern of surviving trials that occurs at any time period (which corresponds to the finite number of letters typed correctly of Shakespeare), even when the observer in Everett box is already dead. Thinking of it as the quantum apparatus does kill, not-kill, not-kill, not-kill and so on for not-kill. This first premise is simply fulfilled by choosing any finite pattern of successful trials in the Everett box. The second premise is that the trial number in MWI must be infinity, in order to create the same infinite monkeys
(corresponding to infinite worlds in MWI) situation. It seems that we may just let the quantity of time go to infinity and fulfill the second premise. However, this premise will not be fulfilled given Pathological Immortality Theorem (PIT) [3], which requires that the quantum apparatus only provides a finite number of trials. Since (ii) represents the situation of pathological distribution [3], we cannot achieve IMT (ii) without using the situation in PIT, and having this knowledge of finite trials, the second premise will then not be fulfilled in Everett box in MIT because of this incorrect condition. We now assume that, in MWI Everett box, if there exists a finite number of trials, the chance of locating the surviving world in pathological distribution will get arbitrarily close to 1, so that the chance of surviving will also get arbitrarily close to 1 (Remember that this is just a broad way of thinking about the result of PIT, and its complete proof further extends to the content of RUSS [7], the recursive constructive mathematics). But here we have enough reasonable knowledge to have a glimpse of the theorem of PIT [3].

Theorem 3 (Pathological Immortality Theorem). While classically it is impossible that an observer in an Everett box remains alive as the number of trials tends to infinity, there is a computable probability distribution on the trials such that the probability that the observer is alive after any finite number of trials is arbitrarily close to 1.

Proof. The idea of recursive constructive mathematics helps prove MIT and then follows by PIT. [6] After a finite number of trials, being alive is small in a computational sense. While pathological distribution will only occur if the observer remains alive after finite trials, this chance of remaining alive gets arbitrarily close to 1. [3]

Note that the validity of Pathological Immortality Theorem is based on one important circumstance—having variable possibilities in each trial. This means that only if the quantum apparatus gives varying possibilities of the two opinions in each trial, PIT will work since its fundamental circumstance is fulfilled.

5. Solution for Pathological Distribution Theorem

In section 2, it is stated that in an experiment “like” the Everett box, the possibility of each result is 50%. Everett did not state such a thing (but 50% as an accepted general quantity), and he gives no specific quantity for the possibility of the two actions of the apparatus.[1] Since we still don’t know what exactly Everett himself thinks about the possibility distribution of that quantum apparatus, let’s now assume that the possibility distribution of the apparatus varies in each trial, in order to fulfill the condition in Pathological Immortality Theorem. Now, suppose that the observer in Everett box has already survived for a sufficiently finite number of trials in PIT. We call this situation P. Then we have two possible types of world: MWI or non-MWI. Both of the twos are able to be in a pathological distribution situation by giving varying possibilities. For Non-MWI, its possibility to achieve P is so small that the observer must reject this possibility. [3]

Another way of saying it is that, in any number of trial in non-MWI, the surviving situation P does not hold because the observer will very likely die once the varying possibility distributes to a, let’s say, 99% chance of dying. This 99% chance of death could occur at any trial in non-MWI, and if it occurs for just one time, the observer is very likely to die in that one trial in non-MWI.

Dividing each varying possibility of death in one trial to 99 fractions of percentage, we have

\[0.01, 0.02, 0.03... 0.97, 0.98, 0.99\]

Therefore the possibility of getting distributed a 99% chance of death will be

\[\frac{1}{99}\] (11)

Compared to the sufficiently large number of trials of survival in P, this probability of death seems to be very likely to occur in a non-MWI world. While MWI, with varying possibilities, can always survive in such pathological distribution condition since every time the observer survives, the amount
of superpositions of worlds gets bigger and bigger, almost certain to achieve P. [3] In other words, every time the superpositions of possibilities in MWI vary but still are realized by the MWI, since the fundamental feature of MWI won’t change even with pathological distribution situation presenting, making MWI worlds more and more certain to achieve P. Thus MWI is more likely to have a successful, consecutive quantum immortal state of the observer. This idea, in Corollary 1 [5], is similarly described in the situation of Infinite Monkey:

**Corollary 1.** Any list of finite strings is completed in finite time with arbitrarily small probability. Therefore non-MWI could not even get close to achieve P because of its small probability with, furthermore, just one “monkey” presenting and trying to reach success. What’s more, as those surviving trials gradually approaches infinity, the possibility of the existence of pathological distribution worlds in MWI gradually turns to one. Proof by the exact same way of calculation process and result presented in Theorem 1(m turns to the infinity of worlds and w being the amount of trials). Thus, with plausible worlds in MWI that can be pathologically distributed, the observer in P can only state that he is in a MWI universe of pathological distribution instead of non-MWI.

### 6. Discussion

Talking about achieving quantum immortal state, even the alive-guaranteed world in MWI is not needed to be considered in pathological distribution since the possibility of being in that world after a sufficient number of trials is sufficiently close to 0. That is because by calculating the ratio of that alive-guaranteed world and the overall number of worlds, we get 1 over a sufficiently large number (and the result won’t change even with this factor presenting).

While thinking back to the origin of the idea of Quantum Immortality, such as when this idea first occurred in humans’ minds, we never gain any useful information on how to apply the idea into a sense of reality. Despite those people who lustfully imagine how great their lives would be if they become immortal or achieve anti-aging, we know that even by assuring a person with a high probability of surviving in any accident or disaster, there can never be any guarantee of that person’s body cells or atoms not performing oxidation every day to stop the body-aging in a biological aspect. Similarly, all these mathematical ideas in this paper do not provide any useful information for these ambitious people. However, it is indeed worth a think about why immortality is impossible, or possible, in order to understand these illogical thoughts about possibilities distributions mathematically in experiments such as Everett box and Infinite Monkey. By doing these calculations, we get many overwhelmingly different and surprising ideas compared to just thinking them in a common and logical sense. It is needed to know that being immortal is not such a thing so impossible that it makes a person ashamed when pursuing such a goal. By generating ideas and theorems, we may even be able to invent instruments or discover laws that turn Quantum Immortality into a much more interesting and worthy topic in the future.

### 7. Conclusion

In the classical Everett experiment, the MWI interpretation stands out simply because of its quality of achieving at least one alive world, thus giving a guarantee of immortality. The infinite Monkey experiment helps provide a sense of the immense amount of possibility, figuratively and explicitly, in a scope of infinity. Follows Theorem 1 that offers the proof that the consecutive achievement of something with a possibility of failing each time will certainly occur only when infinity opportunities exist, favoring the MWI. The MIT theorem draws out how a situation is regarded as pathologically distributed and the PIT brings the way of how a finite number of trials changes the perspective of possibility in MWI and thus makes it reasonable to achieve immortality certainly. Proving non-MWI’s impossibility in achieving quantum immortal state, we find the possible solution of MWI in surviving by utilizing the knowledge of pathological distribution. The conclusion, therefore, states that MWI always theoretically becomes the winner in achieving the quantum immortal state in any experiment similar to the quantum gun experiment.
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