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Do Cats Collapse the Wave Function? Confronting the Measurement Problem with Subliminal Priming

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Abstract

Two experiments were conducted to address the measurement problem in quantum mechanics by leveraging the effects of subliminal priming, a well-developed research paradigm in cognitive psychology, to determine if conscious observation causes the wavefunction to collapse. In both experiments stimulus primes derived directly from patterns in a local source of radioactive decay were flashed on a screen for a duration of time too brief to be consciously experienced. They were immediately followed by a stimulus that participants were asked to rapidly respond to. The stimulus was designed to be congruent with some primes and incongruent with others. If observation caused collapse, the primes, having been shielded from observation, should continue to exist in a state of superposition based on the radioactive decay from which they were derived. Before the participants took the reaction time test, a third of the primes were observed by the experimenter, a third remained completely unobserved, and a third were observed by a cat. If consciousness caused collapse, shorter response time differences would be expected in the primes that remained unobserved as opposed to those previously exposed to observation. Consistent with previous research, primes subjected to prior human observation had a greater effect on reaction time than those that were denied that observation. Primes previously observed by the cat did not have any greater effect than those that remained completely unobserved, a finding which suggests that wave function collapse may be tied to a feature of human consciousness which is not universally shared.

Key Words: consciousness, quantum, wave function, measurement problem

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Introduction

Experimental methods in cognitive psychology have advanced to the point that they may be able to contribute clarity to metaphysical questions. Perhaps no metaphysical question is more fundamental than the question: what is the primary constituent of reality?

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Physicalists claim that only physical things exist (e.g., Dennett 1991, Ryle, 1949). While non-physicalist philosophers contend that consciousness, a nonphysical entity, is in some way fundamental. Dualists contend that the world can be divided into a physical and nonphysical domain, where both aspects of reality are fundamental (Chalmers, 1995, Nagel, 1974). In contrast, Idealists contend that consciousness is the fundamental constituent of reality and that what appears to us to be the physical universe is itself dependent on consciousness (Berkeley, 1881; Kastrup, 2018). Finally, Neutral Monism holds that consciousness and physical reality are both derived from a neutral substance (Goff, 2017; Russell, 1921). Although adherents have historically advocated for their chosen positions primarily by means of analytical argument, these four positions can also be regarded as potentially falsifiable scientific hypotheses. The measurement problem in quantum mechanics has been postulated by many non-materialists to be a choke point between the physical universe and consciousness (e.g., Chalmers 1996, Stapp, 2003), and we may now be at the point where we can utilize cognitive psychology to exploit this choke point to arrive at an empirical answer to this metaphysical question.

Quantum mechanics is the foundation of physical theory, whose predictions have been consistently verified. However, the manner in which the mathematics must be formulated stands at odds with previously assumed to be unassailable truths of physical logic. The idea that a superposition (simultaneous manifestations of mutually exclusive properties) exists between measurements of quantum phenomenon is incongruent with the notion of objective realism: the idea that external objects exist irrespective of observation. In spite of this incongruence, experimental work has consistently supported the notion in quantum mechanics that microphysical reality bends to measurement and not the other way around (e.g., Aspect, 1999; Gröblacher et al, 2007; Hensen et al, 2015; Jacques et al, 2007).

To explain experimental results, researchers have postulated different interpretations of quantum mechanics. In the standard orthodoxy, often referred to as the Copenhagen Interpretation, particles exist in a state of superposition, a collection of all possible states described by Schrodinger's wave function, until the act of measurement, at which time the superposition collapses into only one of these possible states. The Copenhagen Interpretation is silent on what actually constitutes an act of measurement or on how or why it collapses the wave function. Unsatisfied with this lack of clarity, other interpretations have emerged that contest the reality of the superposition. For example, the Many Worlds interpretation (Everett, 1957) holds instead that the universe bifurcates every time a measurement is taken on a quantum system, that all the possibilities are actually realized. Other interpretations maintain that nonlocal hidden variables determine the results of each measurement (Bohm, 1980), or that the collapse of the wave function is a spontaneous yet objective process where collapse does not occur upon the interaction with a physical measurement device. (Ghirardi, Rimini, & Weber, 1986).

Consciousness enters the conversation in the augmentation to the Copenhagen interpretation suggested by John von Neumann (1932) and Eugene Wigner (1961). This interpretation holds that there is no clear physical end to the superposition, and that the mathematics allows for the collapse of the wave function to be placed anywhere on the causal chain from the physical measurement device all the way to the experimenter's subjective perception. In other words, when a particle in superposition interacts with a physical measurement device, it is reasonable to conclude that both the particle under consideration along with the physical measurement device itself are existing in a state of superposition until they are observed by the experimenter. What reason is there to conclude that macrophysical objects persist objectively in time while microphysical objects exist only in superposition? The only clear place to draw the line of collapse is at the point where a physical system interacts with consciousness, something that is outside of the physical reality that is governed by quantum mechanics. This has subsequently become known as the Consciousness Causes Collapse (CCC) interpretation.

In the years since its inception, the CCC interpretation has been further developed by researchers in a variety of disciplines, (Beck & Eccles, 1998; Stapp, 2003, Lanza & Berman, 2009). However, the interpretation remains unpopular. A recent poll among working physicists, mathematicians, and philosophers found that only six percent of the respondents thought that the observer had a role in collapsing the wave function (Schlosshauer, Koer, & Zeilinger, 2013). Nevertheless, interest in the CCC interpretation persists into the present day by researchers who continue to argue that it remains a viable way to interpret quantum mechanics (Chalmers & McQueen, 2022, Kent, 2021, Levin, 2023).

Putting the CCC interpretation to an empirical test will require methods that are not limited to those of experimental physics. In cognitive psychology the term priming refers to an effect where exposure to one stimulus influences a person's response to another stimulus. For example, a positive word such as “happy” is recognized and responded to faster after the word “joy” as compared to a negative word such as “sadness” or “death”. The word “up” is responded to faster following a prime such as “high” or “top” as opposed to “bottom” or “low”. Psychologists have been exploiting these reliable reaction time effects for decades as a multipurpose research tool. In recent years, these methods have even been used to prime subjects subliminally (Dehaene et al, 1998; Greenwald et al, 2003; Kouider & Dehaene, 2009). In such research, subjects are shown a prime (such as a word or a symbol) on a computer screen for a length of time that is just underneath the duration that can be consciously experienced (about 50 milliseconds). Despite subjects reporting to not be aware of seeing the primes, they demonstrated shorter reaction times responding to stimulus that is congruent with the primes than to incongruent stimulus. Their brains processed the meaning of the primes and began to react to them even though they were not aware of it. The primes were processed unconsciously. This ability of humans to process information unconsciously makes it possible to measure the effects of something that is itself shielded from conscious observation. By deriving the direction of the primes from quantum events we can leverage the methodology of subliminal priming to put the CCC interpretation of quantum mechanics to an experimental test.

The research presented here is an attempt to replicate two previous tests of the CCC interpretation using subliminal priming (Lucido, 2023, 2024). In these studies, a sequence of primes was derived from the radioactive decay frequency of a small sample of uranium ore. These primes, which consisted of single digit numbers 1-9, were shielded from any interaction with consciousness. The primes were then paired with stimulus items (also one-digit numbers) that the participants were asked to rapidly respond to, indicating whether they were odd or even. The time it took to respond was measured. Based on past research it was expected that the stimulus items that were preceded by congruent primes (e.g., odd/odd or even/even) would be responded to faster than items preceded by incongruent primes (e.g., odd/even or even/odd). However, since the primes had yet to be exposed to conscious observation, according to the CCC, they should not have yet collapsed into a definite state (i.e., an odd or even number). They should still be in a state of superposition of all the one-digit whole numbers, thereby being both odd and even at the same time. A prime in a state of superposition should not have the same effect on reaction time as a prime that is in a definite state. Before each trial the experimenter directly observed half of the primes, and only half of the primes that were used. Participant response times to stimulus items preceded by these "observed" primes populated the observed condition, and response times to items preceded by primes that had yet to be observed populated the unobserved condition. In both studies, the primes that were subjected to prior human observation generated significantly greater response time effects as compared to primes that were denied that observation. In the first study (Lucido, 2023), within the observed condition, items preceded by congruent primes were responded to 37 ms faster than items preceded by incongruent primes. In contrast, within the unobserved condition items preceded by congruent primes were responded to only 9 ms faster than items preceded by incongruent primes. This resulted in an average response time difference of 28 ms between the two groups. The results met the criteria for statistical significance in the observed condition ($t=-3.19$, $p<.001$), but not the unobserved condition ($t=-0.71$, $p=0.239$). In the second study (Lucido, 2024) within the observed condition, items preceded by congruent primes were

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responded to 47 ms faster than items preceded by incongruent primes. However, within the unobserved condition, items preceded by congruent primes were responded to only 17 ms faster than items preceded by incongruent primes. Although both conditions met the .05 cut off for statistical significance, the t value obtained in the observed condition (t=-5.65) was nearly three times as large as the value obtained in the unobserved condition (t=-2.00). The absolute difference in the t values between the two conditions was 3.65. This result was statistically significant. It was larger than what was obtained in the first study. The probability of obtaining a t value difference of 3.65 by chance is .00014.

A secondary goal of the present research is to vary two design features in an attempt to reduce potential sources of inadvertent collapse in the unobserved condition. In the replication study (Lucido, 2024) larger differences were found between congruent and incongruent primes in the unobserved condition than were present in the first study (Lucido, 2023). This may have been due to the response modality. In the first study participants responded verbally by saying the words “odd” or “even” and the second study participants responded by hitting keys to indicate odd or even. It may be that the verbal response modality works to cut down inadvertent collapse in the unobserved condition. To evaluate this further the experiments presented here will vary the response modality, where experiment #1 will require subjects to respond verbally, and experiment #2 will employ a keystroke response. It was also postulated that the prime exposure time of 50 ms may be long enough to collapse some of the primes when they were viewed by the participants. In experiment # 2, this exposure time was reduced to 33 ms to see if a shortened exposure time would reduce the effectiveness of the primes in the unobserved condition.

Hypotheses

A sequence of stimulus primes will be derived directly from quantum events without any contact from a conscious observer. According to the CCC interpretation, these primes, having not yet been exposed to conscious observation, will have yet to collapse into an exact state. These primes, still in a state of superposition, will be paired with stimulus items that the participants will be asked to rapidly respond to. Once derived, the experimenter will observe one third of the primes, a cat will observe one third of the primes, and the remaining third will be left completely unobserved. The participants' response times to stimulus items immediately following the primes will be measured and the performance of the primes will be compared across these groups.

A prime in a state of superposition should not have the expected effect on response time as it will be simultaneously both congruent and incongruent with the stimulus. Therefore, it is hypothesized that if the CCC interpretation of quantum mechanics is correct, the stimulus primes will have a diminished effect on reaction time (reducing it when congruent and increasing it when incongruent) in the unobserved condition as compared to the human and cat observed conditions.

Methods

Stimulus Response Task

For both experiments the stimulus items were drawn randomly from the set of whole numbers 1-9, where each stimulus item consisted of a single digit number. The primes were similarly drawn from the set of whole numbers 1-9, where each prime was also a single digit number. Upon viewing the stimulus items the subjects were asked to respond as quickly as possible to each number indicating whether the number was odd or even. The time it took for the participants to respond with their answer was measured automatically by the computer program to an accuracy of 1 millisecond. In experiment #1, the participants were asked to respond verbally by saying the words “odd” or “even” into the laptop microphone. In experiment #2, they were asked to respond by pressing the “E” key for even and the “O” key for odd.

For each trial, participants were asked to respond to a set of 81 stimulus items. During the trials the program proceeded automatically through the items with a 1.5 second interval in between each item. Each item began with a forward mask, a nonsense series of symbols that remained on the screen for a duration of 167 milliseconds. This was immediately followed by a prime that remained on the screen for 5o milliseconds in experiment #1 and for 33 milliseconds in experiment #2. The prime was followed by a backwards mask (a different series of nonsense symbols) that remained on the screen for a duration of 33 milliseconds, followed by the presentation of the stimulus symbol, which remained visible for a duration of 1,000 milliseconds or until the participant responded to the item. The stimulus symbols, consisting of the numbers 1-9, were randomly assigned by a deterministic function within the computer program. The interval between the presentation of the stimulus and the participant's response was recorded in the program along with the response itself.

Because of the set up just described, sometimes odd numbered stimulus items followed odd numbered primes, and sometimes even numbered stimulus items followed even numbered primes. In these cases, the primes were labeled as being congruent with the stimulus items. However, in other cases, odd numbered stimulus items followed even numbered primes and even numbered stimulus items followed odd numbered primes. In these cases, the primes were labeled as being incongruent with the stimulus items.

Preparation of the Primes

A Geiger counter was used to measure radioactive decay from a small sample of uranium ore during a series of four second intervals of time. Using Arduino software and related circuitry the number of Geiger counter clicks obtained during each four second interval was automatically transformed into a series of digital values that were fed into a laptop computer. The Geiger counter, uranium ore, the laptop, and the related circuitry were placed within a sound insulated room for the duration of time in which data from the radioactive decay was being taken (about 10 minutes).

After each 10-minute data gathering period, the experimenter reentered the room and removed the laptop to a second room. The experimenter covered the screen of the laptop with a wooden clipboard so that the contents of the screen could not be seen. The experimenter used keystrokes to unlock the computer, and then using the copy function transferred the Geiger counter data (about 150 digits) out of the Arduino Uno program interface and closed the program. The experimenter then removed the screen covering and opened up the response time program (Inquisit 6 Software). The experimenter then scrolled down to the section in the code where the numerical data from the Geiger counter clicks needed to be inserted. When inserting the primes for the unobserved condition, the experimenter covered the screen and pasted in the Geiger counter data using keystroke functions, thus never having had any conscious experience with the number sequence generated from the radioactive decay. However, when pasting in the prime sequence in the observed condition, the experimenter did not cover the screen and simply looked at the list of numbers for a few seconds after pasting them in the code. The cat observed condition was created in exactly the same manner as the unobserved condition except the cat was in the room during the data gathering period. The sound that was made by the Geiger counter appeared to be loud enough for the cat to hear it no matter its position within the room. Once the primes were inserted in the code for all three conditions the program was set for the participants. The experimenter carried the laptop into a third room where the participant was waiting. The laptop was put in front of the participant who initiated the start of the stimulus presentations with a mouse click.

Correspondence of the Primes

The program code had been set up in such a way so that the frequency of Geiger counter clicks pasted in the code became associated with a different whole number prime 1-9. There were eleven different sets of

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these correspondences. The correspondence set that was used was also determined by a blind cut and paste from the Geiger counter data. By basing both the sequence of primes and their correspondence directly on the Geiger counter data, a situation was created where two collapses needed to occur before the exact nature of each prime could be determined. This was done for the purpose of preventing against possible quantum backfilling in the unobserved condition, whereupon their eventual collapse during the data analysis items with a larger response time would be more likely to pull incongruent primes and items with shorter response times would be more likely to pull congruent primes. It was thought that the significant increase in complexity of the possible outcomes within the superposition that this would entail would work to prevent this from occurring.

Participants

Six different participants were used to produce response time data for each study. Each participant was administered a series of either seven or eight trials each containing 81 items, for a total of 43 trials overall (22 trials in experiment #1 and 21 trials in experiments #2). Each of the trials consisted of 27 items from the human observed condition, 27 items from the unobserved condition, and 27 items from the cat observed condition. These were broken up into sections of 9 items at a time to control for order effects (i.e., 9 human observed, 9 unobserved, 9 cat observed, then 9 human observed and so on).

Results

Experiment #1

The participants responded correctly to 1,708 items overall (571 in the human observed condition, 573 in the unobserved condition, and 564 in the cat observed condition). Within the human observed condition participants responded to 292 items whose primes were congruent with the stimulus number and 279 items whose primes were incongruent, the unobserved condition contained 283 congruent primes and 290 incongruent primes, and the cat observed condition contained 280 congruent primes and 284 that were incongruent. The participants responded incorrectly to 39 items (12 in the human observed condition, 11 in the unobserved condition, and 16 in the cat observed condition). These items were excluded from the analysis. Lastly, 35 additional items were spoiled over all three conditions due to a combination of subject error, experimenter error, or the failure of a prime to be generated for an item. For certain analyses a composite of the unobserved and the cat observed conditions termed the human unobserved condition was created. When t scores were derived for this composite condition the degrees of freedom were reduced by half to provide for a fair comparison to the human observed condition, which contained half the number of items.

Table 1. Response Time Means in Milliseconds and Standard Deviations Across Primes & Conditions

	Incongruent Primes		Congruent Primes				
	M	SD	M	SD	Diff	*t*	*p*
Human Observed	657.63	114.66	613.34	120.00	44.29	-4.50	.000004
Human Unobserved (Unob + Cat Obs)	641.80	100.71	620.97	116.38	20.83	-2.28	.011
Unobserved	632.83	89.43	601.83	103.81	31.00	-3.83	.00007
Cat Observed	650.96	110.47	640.32	126.06	10.64	-1.07	.14

Table 1 presents participant response times across experimental conditions. Independent samples t-tests were used to analyze the differences. The stimulus primes affected participant response times in both the human observed condition (t=-4.50, p=.000004) and the human unobserved condition (t=-2.28, p=.011). While both t scores met the cut off for statistical significance, the response time difference between congruent and incongruent primes within the observed condition was more than twice as large as it was within the unobserved condition (44.29 vs 20.83 ms). The absolute value of the t differences between the two conditions (t=2.22) was itself statistically significant (p=.013). A result indicating that the primes had a significantly greater effect within the human observed condition than they did within the human unobserved condition.

The effectiveness of the primes varied significantly within the human unobserved condition. The primes left completely unobserved resulted in significant effects on reaction time (t= -3.83, p=.00007). These primes that remained completely unobserved had less of an effect than those within the human observed condition, but this difference did not reach the level of statistical significance. In contrast, the primes in the cat observed condition did not produce any statistically significant difference in reaction time (t=-1.07, p=.14). The absolute value of the t score difference between this condition and the human observed condition was statistically significant (t=3.43, p=.00032).

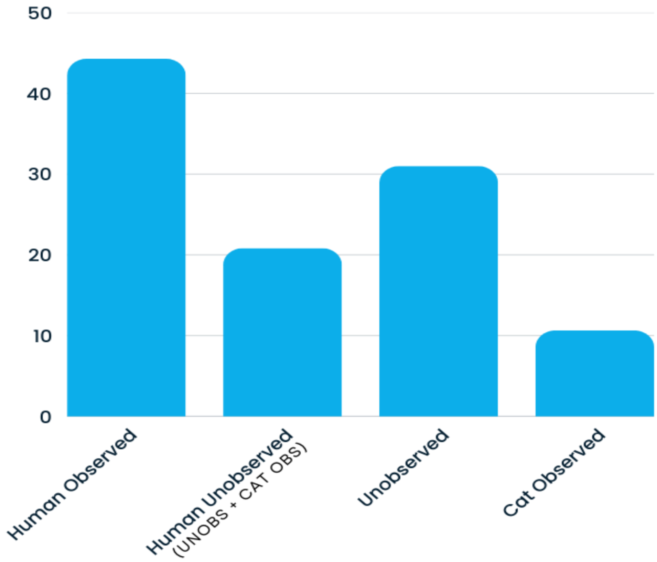

Figure 1. Time Diff Between Congruent and Incongruent Primes Across Conditions Experiment # 1

Experiment #2

The participants correctly responded to 1559 items overall (523 in the human observed condition, 517 in the unobserved condition, and 519 in the cat observed condition). Within the human observed condition participants responded to 251 items whose primes were congruent with the stimulus number and 272 items whose primes were incongruent, the unobserved condition contained 257 congruent primes and 260 incongruent primes, and the cat observed condition contained 259 congruent primes and 260 incongruent primes. The participants responded incorrectly to 33 items in the human observed condition (10 errors occurred on items with congruent primes and 23 occurred on items with incongruent primes) 36 in the unobserved condition (8 occurred on items with congruent primes and 28 on items with incongruent primes), and 37 items within the cat observed condition (11 occurred on items with congruent primes and 26 occurred on items with incongruent primes. The error rates were statistically equivalent across groups (X^2=.726, p =.695) and these items were excluded from subsequent analysis. Lastly, 36 additional items were removed from the analysis across the three conditions due to a combination of subject error, experimenter error, or the failure of a prime to be generated for an item. As in experiment #1, for certain analyses a composite of the unobserved and the cat observed conditions termed the human unobserved condition was created. When t scores were derived for this composite condition the degrees of freedom were reduced by half to provide for a fair comparison to the human observed condition that contained half the number of items.

Table 2. Response Time Means in Milliseconds and Standard Deviations Across Primes and Conditions

	Incongruent Primes		Congruent Primes				
	M	SD	M	SD	Diff	*t*	*p*
Human Observed	452.58	96.38	404.58	97.60	48.00	-5.66	.000000013
Human Unobserved (Unob + Cat Obs)	429.44	74.50	412.16	99.89	17.28	-2.23	.013
Unobserved	433.07	78.88	409.51	94.51	23.55	-3.08	.001
Cat Observed	425.82	69.80	414.78	105.07	11.03	-1.41	.079

Table 2 presents participant response times across experimental conditions. Independent samples t-tests were used to analyze the differences. The stimulus primes affected participant response times in both the human observed condition (t=-5.66, p=.000000013) and the human unobserved condition (t=-2.23, p=.012). While both t scores met the cut off for statistical significance, the response time difference between congruent and incongruent primes within the observed condition was more than twice as large as it was within the unobserved condition (48.00 vs 17.28 ms). The absolute value of the t differences between the two conditions (t= 3.43) was itself statistically significant (p= .0003). A result indicating that the primes had a significantly greater effect within the human observed condition than they did within the human unobserved condition. 184

Within the human unobserved condition, the primes that remained completely unobserved produced significant effects on reaction time (t=-3.08, p=.001), but this effect was less than half the size of what was obtained in the human condition. The absolute value of the t difference between these two conditions (2.58) was itself statistically significant (p=.0051). The primes in the cat observed condition did not produce any statistically significant difference in reaction time (t=-1.41, p=.08). The absolute value of the t score difference between this cat observed condition and the human observed condition (t=4.25) was itself statistically significant (p=.000013).

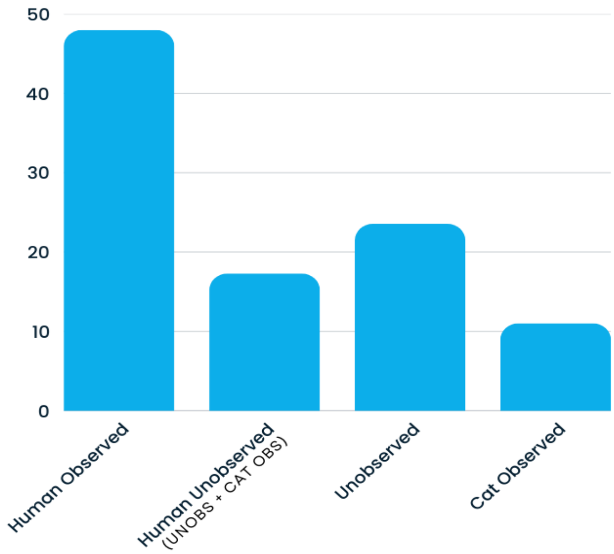

Figure 2. Response Time Diff between Congruent & Incongruent Primes Across Conditions Experiment # 2

Discussion

In both experiments significantly, greater response time effects were obtained using primes that were subjected to prior human observation as compared to primes that were denied that observation. This result indicates that at least some of the wave functions determining the primes in the human unobserved conditions were still in a state of superposition when the participants responded to the stimulus items. Otherwise, if they had all collapsed into definite states upon their interaction with the Geiger counter, they should have had the same effect on response times as they did in the observed condition. The results of both experiments are consistent with those of the previous research. The differences in response times between the human observed and human unobserved conditions (24 & 31 ms) were close to the difference of 28 ms obtained in the original study (Lucido, 2023) and the difference of 30 ms obtained in the replication (Lucido, 2024). The t values obtained by the human observed primes in both experiments were more than twice as large as the *t* values in the human unobserved conditions. The absolute differences in the *t* values between the conditions in both experiments were themselves statistically significant. If physicalism is correct, then this should not have happened. It should make no difference if the primes are observed or not. These results provide additional empirical support for the CCC interpretation of quantum mechanics, and by extension, non-physicalist metaphysics (i.e., dualism, idealism, neutral monism).

Additionally, in both experiments the primes previously observed by the cat did not have any greater effect than those left totally unobserved. There is no reason for this result that can be offered at present as to why primes observed by the cat would underperform primes that remained completely unobserved as they did in experiment #1. However, one conclusion is clear, the observation of the cat resulted in markedly lower effectiveness of the primes compared to those subjected to human observation, which means, barring any unknown errors in the experimental design, that human observation collapses the wavefunction while cat observation does not. A finding which suggests that wave function collapse may be tied to a feature of human consciousness which is not universally shared. It is also possible, although not likely, that relying on the proximity of the cat to the sound of the Geiger counter may have been an insufficient method of producing cat observed primes. If this were the case, then what was designed to be the "cat observed" condition would then have defaulted to an additional unobserved condition. In either scenario the primary result, that human observed primes are more effective than primes that were denied that observation, would remain unchanged.

Finally, in addition to the primary purpose of testing the CCC, the foregoing experiments were attempts to gather more information that may improve the experimental protocol by varying the response modality and the length of time in which the primes were presented. It appears that the verbal response modality does not have any advantage over the keystroke response modality. Of the four experiments conducted so far, the two that used the keystroke response modality generated higher t score differences between observed and unobserved primes than the two that required the participants to respond verbally. For this reason, along with its ease of use, keystroke responses may be preferred in follow up research designs. Secondly, limiting the duration of the primes to 33 milliseconds did not result in any significant difference compared to the other data collections. Follow up research designs may prefer to utilize the 50-millisecond duration of prime exposure.

Although the primes subjected to previous human observation had significantly larger effects than those denied that observation, differences in response times between items preceded by congruent and incongruent primes were still found within the human unobserved condition. One way to interpret this result is to assert that it is likely that some of the items in the unobserved condition collapsed inadvertently due to a potential combination of decoherence, experimenter error, or some individual participants being conscious of some of the primes. What we are likely comparing is a group where 100% of the primes have undergone collapse in the human observed condition to a group where only a subset of primes have undergone collapse in the human unobserved conditions. Due to the original study not having these significant differences within the unobserved condition, it was thought that the verbal response modality, a feature that was not shared with the replication, could be the reason why.

Similarly, the attempts to change the duration of the prime presentation from 50 ms to 33 was an attempt to reduce the possibility that some of the participants could have been conscious of some of the primes. Both strategies to reduce the difference in the unobserved conditions did not work. Future improvements in the experimental protocol are needed that may reduce these differences and lead to a clearer effect of no significant differences within the unobserved condition, such as what was obtained in the first study.

Conclusions

In both experiments significantly, greater response time effects were obtained using primes that were subjected to prior human observation as compared to primes that were denied that observation. The differences in response times between the human observed and human unobserved conditions in the present studies are similar to the differences obtained in prior research. These results provide additional empirical support for the CCC interpretation of quantum mechanics. Primes subjected to previous observation by the cat did not have any greater effect than those that remained completely unobserved, a finding which suggests that wave function collapse may be tied to a feature of human consciousness which is not universally shared.

References

Aspect A. Bell's inequality test: more ideal than ever. *Nature*. 1999;398:189-190.

Beck F, Eccles JC. Quantum processes in the brain: A scientific basis of consciousness. *Cogn Stud Bull Jpn Cogn Sci Soc*. 1998;5(2):95-109.

Berkeley G. *A Treatise Concerning the Principles of Human Knowledge*. Philadelphia, PA: J.B. Lippincott & Co.; 1881.

Bohm D. *Wholeness and the Implicate Order*. London, UK: Routledge; 1980.

Chalmers D. Facing up to the problem of consciousness. *J Conscious Stud*. 1995;2(3):200-219.

Chalmers DJ. *The Conscious Mind: In Search of a Fundamental Theory*. Oxford, UK: Oxford University Press; 1996.

Chalmers D, McQueen KJ. Consciousness and the collapse of the wave function. In: Gao S, ed. *Consciousness and Quantum Mechanics*. Oxford, UK: Oxford University Press; 2022.

Dehaene S, Naccache L, Le Clec' H, et al. Imaging unconscious semantic priming. *Nature*. 1998;395(6702):597-600.

Dennett DC. *Consciousness Explained*. Boston, MA: Little, Brown and Company; 1991.

Everett H. On the foundations of quantum mechanics [PhD thesis]. Princeton, NJ: Princeton University, Department of Physics; 1957.

Ghirardi GC, Rimini A, Weber T. Unified dynamics for microscopic and macroscopic systems. *Phys Rev D*. 1986;34(2):470-491.

Greenwald AG, Abrams RL, Naccache L, Dehaene S. Long-term semantic memory versus contextual memory in unconscious number processing. *J Exp Psychol Learn Mem Cogn*. 2003;29:235-247.

Gröblacher S, Paterek T, Kaltenbaek R, et al. An experimental test of non-local realism. *Nature*. 2007;446(7138):871-875.

Goff P. *Consciousness and Fundamental Reality*. Oxford, UK: Oxford University Press; 2017.

Hensen B, Bernien H, Dréau A. Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometers. *Nature*. 2015;526:682-686.

Jacques V, Wu E, Grosshans F, et al. Experimental realization of Wheeler's delayed-choice Gedanken experiment. *Science*. 2007;315:966-968.

Kastrup G. *The Idea of the World: A Multi-Disciplinary Argument for the Mental Nature of Reality*. Collective Ink; 2019.

Kent A. Collapse and measures of consciousness. *Found Phys*. 2021;51(3):1-14.

Kouider S, Dehaene S. Subliminal number priming within and across the visual and auditory modalities. *Exp Psychol*. 2009;56(6):418-433.

Lanza R, Berman B. *Biocentrism: How Life and Consciousness Are the Keys to Understanding the True Nature of the Universe*. Dallas, TX: BenBella Books; 2009.

Levin E. The presentiment effect points to an occurrence of a von Neumann's collapse. *J Anomal Exp Cogn*. 2023;3:174-193.

Lucido RJ. Testing the consciousness causes collapse interpretation of quantum mechanics using subliminal primes derived from random fluctuations in radioactive decay. *J Conscious Explor Res*. 2023;14(3):185-194.

Lucido RJ. Replication of results from a test of the consciousness causes collapse interpretation of quantum mechanics using subliminal priming methodology. *J Conscious Explor Res*. 2024;15(3):229-239.

Nagel T. What is it like to be a bat? *Philos Rev*. 1974;83:435-450.

Russell B. *The Analysis of Mind*. London, UK: George Allen & Unwin; 1921. Reprinted 1978.

Ryle G. *The Concept of Mind*. London, UK: Routledge; 1949.

Schlosshauer M, Koer J, Zeilinger A. A snapshot of foundational attitudes toward quantum mechanics. *Stud Hist Philos Sci B Stud Hist Philos Mod Phys*. 2013;44(3):222-230.

Stapp HP. *Mind, Matter, and Quantum Mechanics*. New York, NY: Springer-Verlag; 1993/2003.

von Neumann J. *Mathematical Foundations of Quantum Mechanics*. Princeton, NJ: Princeton University Press; 1955. Translated by Beyer RT from the 1932 German original, *Mathematische Grundlagen der Quantenmechanik*. Berlin, Germany: J. Springer.

Wigner EP. Remarks on the mind-body question. In: Good IJ, ed. *The Scientist Speculates*. London, UK: Heinemann; 1961.