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Does A Veridical Libertarian Experience Require Quantum Indeterminacy?

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By

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ABSTRACT

I argue that the question of whether or not all of our choices are determined by the past and the laws of physics requires answering the question of whether or not quantum mechanisms could have a functional role in the parts of our brain that are identical to conscious experience. I take a physicalist position on the mind-body problem as opposed to a dualist position. I present Mark Balaguer's theory of how a libertarian experience might be veridical. I suggest additions to Balaguer's theory that address further what is necessary for libertarian free will. I argue that our choices must be affected by an indeterministic process that occurs within the set of brain processes that are identitcal to consciousness in order for our libertarian experiences to be veridical.

INDEX WORDS: Event-causal libertarianism, Incompatibilism, Balaguer, Kane

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1 INTRODUCTION

When philosophers discuss free will, there are numerous different notions of “free will” that they might be discussing. One such notion of free will is, by definition, incompatible with a notion of determinism. I will use the following definition of determinism throughout this thesis: if the entire history of the universe is held fixed at some moment in time and space, and the laws of physics are held fixed, then there is only one possibility for what will occur at any later moments in time and space (Deery et al. 2013, 127). Since the birth of Newtonian physics and before the advent of quantum mechanics, physicists assumed that the universe was deterministic (Heisenberg 1958b, 97-98). Many people, however, feel as though they have a type of free will that is incompatible with determinism. They feel as though there are times when there are multiple options for what they might do holding fixed the past and laws of physics. This created a puzzle for philosophers to explain the feeling we have when we seem to have multiple options open to us. Some philosophers accepted the conclusion that this feeling was just a delusion. There may be hope, however, now that the field of neuroscience has been born, to find an answer to whether or not the physical processes that correspond to our choices and actions follow deterministic laws.

In his book *Free Will as an Open Scientific Problem* (2010), Mark Balaguer presents a theory of a type of free will that is incompatible with determinism similar to the theory presented by Robert Kane (1998), but Balaguer’s theory hinges less on the issue of moral responsibility. I will suggest additions to Balaguer's theory, I will defend this extended theory against possible objections, and I will present evidence supporting the plausibility of this account. I will argue for the thesis that the question of whether or not all of our choices are determined by the past and the laws of physics depends on the answer to the question of whether or not quantum mechanisms could have a functional role in the parts of our brain that are identical to conscious experience.

First, I will describe some of the philosophical concepts that are relevant to my argument. One philosophical issue relevant to my project is the mind-body problem. The mind-body problem revolves around the question of how the mind relates to the physical body. I will take a physicalist position on the mind-body problem as opposed to a dualist position. Dualism is generally the position that the mind is a non-physical substance apart from the physical brain and body. Variations on dualism exist, however, that do not entirely fit this description, such as property dualism. Physicalism in general is the opposing position that the mental states that constitute the mind are identical to certain physical brain states, where the mental states in question include any conscious experience a person might be having, and a brain state is a physical state of the nervous system. Again, however, there are variations of this position, such as functionalism, anomalous monism, eliminativism, etc. Since neuroscientists have not deciphered yet whether the entire nervous system or just some subset of processes in the nervous system is essential for consciousness, I will simply say that a phenomenal experience is identical to some set of processes in the brain, where this set may or may not include the entire nervous system.[1] In what follows, I will refer to any set of brain processes that is identical to a phenomenal experience as a conscious set of brain processes (CBP).

Another philosophical debate that is obviously relevant here is the debate between libertarians and compatibilists on the issue of the whether or not free will is compatible with determinism. Compatibilists in general hold that the type of free will that is required for moral responsibility is compatible with determinism. They also usually claim that this type of free will is the type that we actually experience ourselves to have. Though there are numerous compatibilist accounts of what is necessary for free will, a more common sufficient requirement

[1] This assumption is not intended to exclude embodied mind theories or extended mind theories.

is that we are able to effectively deliberate over what we want to do and we are able to act on what we have decided we want to do (Deery et al. 2013, 128-129). This condition for free will does not require that we have multiple options metaphysically open to us holding fixed the history of the universe and the laws of physics. Therefore, even if determinism were true, we could still have free will in the compatibilists' sense.

The libertarian position, on the other hand, is that the free will required for moral responsibility and also that we experience ourselves to have is incompatible with determinism. Libertarian free will can be briefly defined as having multiple possible actions that one can perform, holding fixed the history of the universe and the laws of physics. If one experiences that one can freely choose to perform some future action, and one can freely choose not to perform that action, then in the moment that one has this experience, the past has already occurred in one specific way and the world is in one specific state at that moment in time. If it is metaphysically possible that one really can choose to perform the action or choose not to perform the action in this actual universe, then this situation would conflict with determinism. Our experience of deliberating over what choice to make in the future seems libertarian, because we feel as though we have more than one metaphysically possible option in the actual world.

Studies have been conducted in experimental philosophy investigating folk intuitions about whether free will is compatible with determinism. Studies investigating folk intuitions in morally neutral cases suggest that the average person believes that we have a type of free will that is incompatible with determinism (Nichols and Knobe 2207, 669). Studies that involve moral choices, however, have contradictory results; some results suggest that folk intuitions about moral responsibility are incompatibilist, and some results suggest that folk intuitions about moral responsibility are compatibilist (Nichols and Knobe 2007, 666-668), (Nahmias et al.

2005). Therefore, I will assume that our experience has the phenomenological content that we have libertarian free will, and I will not take any position on the issue of whether people generally believe that moral responsibility is compatible with determinism. In other words, I will assume that in at least some cases, right before we make a choice, we feel as though there are multiple options that we could choose, holding fixed the state of the physical universe at that moment in time and holding fixed the laws of physics.

Many philosophers, who are interested in the question of free will, define "free will" in such a way that it is what we need in order to be morally responsible. The question of whether we are morally responsible, however, goes beyond just whether we have free will or not. There are many other factors that would affect whether or not we are morally responsible, such as having a sufficient understanding of ourselves and our situation or having the capability to understand the difference between right and wrong in any given situation. Conversely, if it turns out that we could be morally responsible even if we do not have libertarian free will, I will still want to know whether or not we have libertarian free will. Therefore, I will only be considering a sort of free will that can explain our phenomenological experience of freedom, regardless of whether it may also be necessary for moral responsibility.

Assuming that we have this libertarian experience, it is important that we discover whether this experience is accurately representing reality, aside from the question of whether libertarian free will can offer moral responsibility. If determinism is true, then our experience of libertarian free will could be considered deceptive. It seems unlikely to me that humans would have evolved to have such a high degree of delusion in their experiences. Although there is plenty of evidence suggesting that our visual perceptions are sometimes deceptive, we are constantly making decisions, and I find it unlikely that we are constantly deceived as to whether we actually have multiple options open to us. If we do actually have libertarian free will, then this would mean that we interact with the physical universe in a remarkably strange way that is worth exploring. We would be affecting the world in a way that could not be entirely explained by the laws of physics.

The type of agency that we believe ourselves to have largely affects our conception of our identity. Our identity is strongly tied to how we conceive of our abilities and our role in the world around us. If we do have libertarian experiences, then we experience ourselves to be agents that can determine which direction the world will take in certain situations. The future was undetermined to a certain extent until we made the choice determining which direction the future would take. The experience of making a choice with libertarian free will is also the experience of identifying ourselves as libertarian agents. If our libertarian experiences are illusory, then the conception of self-identity that we adopt while having a libertarian experience is also illusory. It is important for us to understand whether we are who we feel we are.

In the first section below, I will present Mark Balaguer's theory of how this libertarian experience might be veridical. I will then suggest additions to Balaguer's theory. I will argue that an indeterministic process must occur within the set of brain processes that are identical to consciousness in order for our libertarian experiences to be veridical. In the following section, I will argue against possible objections to this extended theory. Finally I will present neuroscientific evidence suggesting that we cannot yet rule out the possibility that quantum indeterminacy could provide a libertarian type of free will.

2 BALAGUER'S THEORY

I will now describe Balaguer's account of libertarian free will. Balaguer (2010) presents the concept of a "torn decision," which he defines as:

> a decision in which the person in question (a) has reasons for two or more options and feels torn as to which set of reasons is strongest, that is, has no conscious belief as to which option is best, given her reasons; and (b) decides without resolving this conflict... (71)

Therefore, a torn decision is a situation in which you make a choice between options, where you do not know which option you desire the most. Examples of such decisions might include choosing where to go on vacation when one desires equally to go to each of the places under consideration. Another example might be deciding between giving to a charity or saving your money in order to provide more for your family. Another possible example might be deciding which cereal box to pick up out of a group of identical cereal boxes at the store. Throughout the book, Balaguer refers to the options which one considers in a torn decision as "reasons-based tied-for-best options." Torn decisions are special, because they are more likely to involve indeterminism. In a decision in which we have more convincing reasons to do one thing as opposed to another, those more convincing reasons tend to control what we will choose. Once we feel as though there is one option that we have more convincing reasons to choose, we do not necessarily feel as though we are making this decision in some indeterministic way. Therefore, we do not necessarily experience using libertarian free will to make this decision.

Balaguer argues that it is possible and even plausible that humans possess a certain type of libertarian freedom, which he calls "L-freedom." He provides the following definition:

> a person is L-free if and only if she makes at least some decisions that are such that (a) they are both undetermined and appropriately nonrandom, and (b) the indeterminacy is relevant to the appropriate nonrandomness in the sense that it generates the nonrandomness, or procures it, or enhances it, or increases it, or something along those lines. (10)

Balaguer defines appropriate nonrandomness as a condition in which a decision is "authored and controlled by the agent in question in an appropriately rational way and in a way that satisfies the requirement for plural authorship, control, and rationality" (84). According to Balaguer's use of the terms, I "authored and controlled" a decision if *I* "consciously, intentionally, and purposefully" made the decision, the "choice flowed out of [my] conscious reasons and thought in a nondeterministically causal way," and nothing external to myself causally influenced the decision at the moment of choice (87). The decision is "rational" if I have reasons for the choice that I make and I do not have over-riding reasons to choose something else, regardless of whether these reasons are conscious or subconscious (114-115). I have plural authorship, plural control, and plural rationality, if in the case that I had made a different decision, I would have rationally authored and controlled the decision (119).

Therefore, he is claiming that if a decision is physically undetermined in such a way that enhances the agent's ability to rationally author and control the decision, then the decision is made with L-freedom. If the physical indeterminism involved in the decision did not correlate with any sort of agential control, then the indeterminism could only involve some sort of random event entirely outside of the agent's control. The feeling of L-freedom that we experience involves some sort of agential control beyond just some random event. Therefore, it is a necessary condition for L-freedom that the indeterminism involved in the decision somehow enhances agential control. Balaguer also argues that this type of indeterminism is a sufficient condition for L-freedom.

Balaguer labels this sort of indeterminacy that would procure agential control as "TDW-indeterminism," and he argues for the following thesis:

> (**) For any ordinary human torn decision, if it is wholly undetermined in the manner of TDW-indeterminism, then it is L-free—that is, (a) it is not just undetermined but also appropriately nonrandom ..., and (b) the indeterminacy in question increases or procures the appropriate nonrandomness. (84)

Balaguer describes further what would have to be entailed by TDW-indeterminsim. He offers the following definition of the condition:

> TDW-indeterminism: Some of our torn decisions are wholly undetermined at the moment of choice, where to say that a torn decision is wholly undetermined at the moment of choice is to say that the moment-of-choice probabilities of the various reasons-based tied-for-best options being chosen match the reasons-based probabilities, so that these moment-of-choice probabilities are all roughly even, given the complete state of the world and all the laws of nature, and the choice occurs without anything else being significantly causally relevant to which option is chosen. (78)

Therefore, if one is making a torn decision between two options, A and B, and 60% of one's reasons are leaning towards A and 40% of one's reasons are leaning towards B, and there is a physical probability of 60% that one will choose A and of 40 % that one will choose B and if nothing external to the agent is causally relevant to the decision at the moment of deciding, then one is in a state of TDW-indeterminism. Balaguer is arguing that his notion of the libertarian freedom that we experience ourselves to have, “L-freedom,” would be veridical if and only if there are at least some cases in which a decision is undetermined in a sense that offers the agent more authorship and/or control over the decision than the agent would have if the decision were physically determined.

Balaguer argues that if a torn decision is subject to TDW-indeterminism, then it is also appropriately non-random (85). He argues that since nothing external to the agent influences the torn decision at the moment of choice, there are no random influences in the appropriate sense (86). External circumstances obviously influence what options we come to consider and influence our reasons for choosing either option, but in the moment of choice, nothing external to ourselves is causally relevant to what we finally decide. According to Balaguer, the concept of a random influence or cause that could impair one's control assumes that the influence or cause has a source that is external to that agent (85). Therefore, if nothing external to the agent influences the torn decision, then the torn-decision is not random in the appropriate sense. It must be admitted, however, that Balaguer is using a weak sense of the term “control” here. By Balaguer’s use of the term, we *control* what we intentionally choose if and only if we cause our choices to occur, and nothing external to ourselves influences the choice at the moment the choice is finalized. Therefore, according to Balaguer, we control the outcome of a torn decision, and this control is enhanced by the indeterminism, because the indeterminism does not allow any external influences to determine the outcome for us. I will consider later whether Balaguer’s sense of control adequately accounts for our experience of control over torn decisions.

Therefore, Balaguer’s thesis could be restated as the claim that, if a human decision is undetermined in the sense that the laws of nature and the history of the universe cannot determine which options will be chosen and that one’s reasons and desires are leaning towards each option equally, then the agent authors and controls the decision of which option is chosen as long as nothing external to the agent causally influences the decision. The question arises, however, what counts as external to the agent? Our surroundings are constantly influencing our decisions, so there is a sense in which they are always causally relevant to our decisions.

3 DEVELOPING BALAGUER'S THEORY

3.1 Defining an Agent

Anything external to the agent that influences a torn decision at the moment of choice threatens the extent to which a decision is appropriately non-random. Therefore, it is important that we delineate what is external to the agent and what is internal to agent. In order to do this, we must define exactly what we mean by "agent," or "self," and consider the bounds of these concepts. Balaguer claims, however, that this definition is not necessary. He states, "I don't have a conceptual theory of what a person is, or what a game is, but I'm still very reliable at distinguishing persons from non-persons and games from non-games" (2010, 89). I would object to Balaguer that we are not always reliable in distinguishing persons from non-persons or agents from non-agents. If we cannot agree on what a person or agent essentially consists of, then we will not be able to agree on what is external or internal to an agent.

I will choose a minimalist definition of "agent," "person," or "self" (used interchangeably), which includes only the small set of properties that everyone agrees are included in an agent. Not everyone agrees that a physical body is included in an agent, or self. Not everyone agrees about whether an agent, or self, exists over an extended period of time. I will define an agent at a certain moment in time as at least consisting of the sum total of one's phenomenal experiences at that moment in time, in other words, one's mental state at that moment in time. If we assume physicalism, these phenomenal experiences are identical to certain brain processes that are occurring at that moment in time. Therefore an agent at some moment in time includes a set of phenomenal experiences at that time that is identical to a certain set of brain processes. Most accounts of the self include one's mind as a part of the self, and most accounts of the mind include one's present mental state as a part of the mind. Therefore, I will consider one's present mental state as internal to the agent.

In order for the experience of L-freedom to be veridical, the experience of the indeterminism involved in L-freedom must correlate with some actual indeterminism in the physical world. I will argue that this physical indeterminism must occur within the set of processes that are identical to consciousness. If some physical matter in the brain that is not identical to phenomenal experience indeterministically causes the outcome of a torn decision, then the indeterminism involved in the choice is external to the agent. The indeterminism would be an external causal effect on the outcome of the torn decision. Therefore, according to Balaguer's use of the term control, the agent did not control the outcome of the torn decision. In order for a person to claim control over the outcome of some indeterminism in the brain, this indeterminism would have to at least have occurred within the set of brain processes that are identical to this person's consciousness.

I will explore what would have to be the case in order for the CBP to have multiple options open to it at the moment of choice. Balaguer does not put forth any positive accounts of how indeterminism could play a functional role in this conscious set of brain processes. He merely objects to arguments claiming that indeterminism could not play a functional role in the brain. I will go ahead and present an account of what would have to be the case in order for a set of brain processes to include an indeterminacy that generates or enhances the extent to which a torn decision is "authored and controlled by the agent in question in an appropriately rational way and in a way that satisfies the requirement for plural authorship, control, and rationality" (84).

First, it is important to realize that any set of biological processes has some input from external sources and some output to external sources. The set of brain processes that is identical to phenomenal experience receives some input from external sources, for example, the rest of the body. In order for the CBP to L-freely make a decision, this physical input cannot determine the physical output. There must be more than one possible output with the same physical input at least in the case of a torn decision. The only known physical mechanism that is not considered to be determined by the entirety of its input, or its initial conditions, is the collapse of a quantum wave function (Beck 2001, 89; Heisenberg 1958a, 19). In the next section, I will provide an introductory description of quantum mechanics, and describe a collapse of a quantum wave function in order to set up an explanation for how such indeterministic events might occur at the appropriate place and time within the CBP so that the experience of L-freedom would be veridical.

3.2 Interpreting Quantum Mechanics

Classical mechanics consists of a set of deterministic laws that can determine the entire future of any sufficiently well understood physical system. In the early 1900's, scientists found that the laws of classical mechanics could not describe or predict what they found on the level of a single atom (Heisenberg 1958a, 7). It seemed as though very small objects did not behave according to the same rules as larger objects. The field of quantum mechanics was created in order to describe these tiny objects.

Classical mechanics makes ontological claims about physical objects that are supposed to exist regardless of an observer (Heisenberg 1958b, 98). Quantum mechanics, however, was initially introduced as a set of laws that describe what we are capable of knowing about some tiny physical system. Therefore, while classical mechanics makes ontological claims about physical objects, quantum mechanics initially made only epistemological claims about physical objects. Quantum mechanics was first extensively formalized in 1927 by Niels Bohr, Werner Heisenberg and others into what is referred to as the Copenhagen interpretation, or the Orthodox interpretation (Heisenberg 1958a, 14). These physicists claimed that this interpretation only described the knowledge that could be gathered about a quantum-level system. The interpretation made no ontological claims about what exists at the quantum-level independent of any observer. Heisenberg stated:

> In consequence, we are finally led to believe that the laws of nature which we formulate mathematically in quantum theory deal no longer with the particles themselves but with our knowledge of the elementary particles. The question whether these particles exist in space and time "in themselves" can thus no longer be posed in this form. (1958b, 99-100)

In quantum mechanics, the position of a single particle at some moment in time is described by a cloud of points in space, where each point is assigned a corresponding probability of finding the particle at this point (Griffiths 1995, 2). All other observable qualities of the particle, such as velocity, energy, etc., are treated similarly to position. Using position as an example, though, if someone measures the position of a particle, this person will find the particle in a certain position, but there are no deterministic laws that can be used to predict with certainty where the particle will be found (Griffiths 1995, 4). Quantum mechanics does offer deterministic laws for how this cloud of probabilities, called a wave function, will change over time (Griffiths 1995, 2). We are still left, however, with only probabilities to use in order to predict where we will find this particle at any moment in time. If we measure this same particle again after some extended period of time, there would be no deterministic laws that we could use to predict with certainty where we will find it. Quantum mechanics does not offer any causal explanation for why a particle shows up where it does.

An important aspect of quantum physics is the Uncertainty Principle. This principle holds that the uncertainty of the value of some observable quality of a system is inversely related to the uncertainty of other observable qualities of the system (Griffiths 1995, 110). Therefore, if the uncertainty in one quality is very small, then the uncertainty in another quality will be very large. For example, suppose a physicist sets up an experiment, in a vacuum, in which a single electron will be fired from a laser at a wall, where the position of the electron will be measured. Suppose the physicist sets up the laser so that the momentum of the electron is known with very little uncertainty. In this case, the final position of the electron at the wall will have a very large uncertainty. This can be demonstrated by repeating this same experiment numerous times. If all of the electrons have the same initial momentum with a small uncertainty, then the final positions of the electrons will be spread out around the wall, providing a visual representation of the wave function of each of these electrons right before it was measured by the wall.

Deterministic interpretations of quantum mechanics were developed, in which some "local hidden variable" was introduced that could be used to formulate laws that determined the future state of a quantum system (Griffiths 1995, 376). The hidden variable was assumed to be local, meaning that it was only influenced directly by processes occurring at the specific position of the particle. In 1964, however, J. S. Bell proved what was later called Bell's Theorem that if any local hidden variable is included in a quantum analysis of the outcome of an experiment, then the quantum analysis will produce an incorrect prediction of the experiment (Bell 1964, 195). Bell's Theorem extended the original Copenhagen interpretation to include the ontological claim that a quantum particle is not in any particular position until someone measures the position of the particle (Heisenberg 1958a, xvi-xvii). Similarly, the particle does not have any specific measurable quality, velocity, energy, etc., until that quality is measured. Bell's Theorem, however, does not exclude the possibility of nonlocal hidden variables, which could be instantaneously influenced by remote occurrences. There are deterministic interpretations of quantum mechanics that include such nonlocal hidden variables. In a recent poll held at a quantum physics conference, however, 0% of physicists sided with a deterministic interpretation of quantum mechanics (Schlosshauer 2013, 2). The Orthodox interpretation is the most prominent interpretation among physicists, as of now (Schlosshauer 2013, 8). In what follows, I will be adopting the Orthodox interpretation of quantum mechanics.

Generally, the number of particles in a collection that constitutes an object that we can see and interact with is so enormous that it behaves deterministically, which can be explained by the deterministic evolution over time of the wave function. In other words, if a collection of particles is large enough, then it qualifies to be analyzed by a classical approximation. However, a system of only a few particles is indeterministic. Such a system can only be measured through a collapse of its wave function.[2] According to the Orthodox interpretation, this collapse of a wave function is the only truly indeterministic physical process in quantum mechanics and in physics in general (Beck 2001, 89; Heisenberg 1958a, 23).[3] Therefore, the collapse of a quantum wave function is the only known physical mechanism that could possibly allow the CBP to have a number of possible outputs with the same input. The CBP, however, consists of an enormous collection of quantum particles, which would lead us to expect that the CBP would behave according to the classical approximation. In the next section, I will explain why we have reason to believe that the CBP does not necessarily always behave according to the classical approximation.

[2] A wave function can be used to describe a collection of particles as well as a single particle (Griffiths 1995, 201).
[3] A transition between states of a quantum system involves wave function collapses. The wave function of the system must already be collapsed on to a certain state in order for there to be an observation that it has changed to a different state. The actual transition to this other state involves another collapse (Heisenberg 1958a, 20-24)

3.3 Quantum Indeterminism in the CBP

In order for a torn decision to be indeterministically settled on an option, there would have to be a system consisting of a small number of quantum particles in the CBP whose behavior could have perceivable macro effects on the behavior of the rest of the CBP. More specifically, for a torn decision, this quantum-level system would have to be positioned such that it could lead the CBP to make a certain choice by collapsing to a specific state. The decision would have to be finalized by a collapse of the wave function of this quantum-level system. After contemplating the torn decision for some amount of time, one has to make some final decision. The experience of finalizing this decision seems almost instantaneous, which Balaguer calls the "moment of choice." If the decision were not finalized by a wave function collapse, then it would be finalized by some approximately deterministic process in the CBP, which would mean that there is only one option, holding fixed all other events, at the moment of choice. If the collapse occurred before the moment of choice, then the decision would be finalized before we experience making the decision, and therefore, our experience of making the choice would not accurately represent how the choice was actually made. Our libertarian experience would not be veridical. If the collapse occurred after the moment of choice, then the actual moment of choice would consist of a deterministic process that somehow leads to a later indeterministic process, which would have to adhere with the choice that was made. In this case, however, the moment of choice again would consist of a deterministic process with only one option. Again, our libertarian experience would not be veridical. Therefore, the decisive wave function collapse would have to occur at the moment of choice in order to leave open the possibility of a veridical libertarian experience.[4]

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[4] This condition does not contradict the Libet experiments. Libet claims that it is possible that there could be a conscious veto process after the brain has begun preparing to enact a decision under consideration. This veto

So far, we have deduced what would be necessary in order for a torn decision to be decided indeterministically. Recall, however, that Balaguer requires that the indeterminacy enhances the "appropriate nonrandomness," namely the agent's authorship and control over the outcome of the decision. In order for us to have L-freedom, the mechanics of this quantum-level system must enhance our authorship and control over the torn decision. Since this system is assumed to be included in the CBP, or the phenomenal experience of the agent, the collapsing of this system's wave function is something that happens within the agent and therefore, there is a sense in which this collapse can be attributed to the agent.

We must consider, however, in what sense this collapse can be attributed to the agent. Many people might claim that if something happens within a tiny subsystem of the CBP, this occurrence is something that happens *to* the agent as opposed to something that the agent *does* (Dennett 2003, 122-124). Consider as an example that I choose to wiggle the toes on my right foot. If brain signals are sent from my CBP down to my toes telling them to initiate wiggling, did *I* send those signals? Considering that my CBP at some moment in time constitutes my mind at that moment in time, if the entirety of my CBP is involved in sending those signals and acts as a unified whole, then the entirety of my mind, acting as unified whole, has sent those signals. *I* wiggled my toes. Suppose now that it is not necessary for the entirety of my CBP to act as a unified whole in order for me to wiggle my toes and to feel as though I have done so voluntarily. Suppose that it is only necessary that some macro-level subsystem within my CBP is involved in initiating the sending of signals to my toes. The rest of my CBP is involved in the rest of my conscious experiences that are happening simultaneously with my beginning to wiggle my toes.

process would allow one to choose to either carry out the action or refrain from carrying out the action (Libet 2002, 292).

In this case, some part of my mind was involved in sending signals to my toes. Did I wiggle my toes, or did the wiggling of my toes just happen to me?

In the field of neuroscience, it is not currently understood which biological processes constitute one's CBP. The boundaries of one's CBP might be constantly changing depending on what one is attending to at the moment. On the other hand, neuroscientists do know a lot about what parts of the brain are involved in sensory perception. If someone pokes the palm of my hand, a signal will be sent from the nerves in my hand and will terminate in a small area of my primary somatosensory cortex (Kandel et al. 2013, 374-376). It is entirely plausible that my phenomenal experience of a touch on my hand is implemented solely by this section of my primary somatosensory cortex. In this case, it is not necessary for my CBP to be involved in its entirety in every phenomenal experience. It also seems entirely plausible that this section of my primary somatosensory cortex does not need to be involved in the initiation of toe wiggling. Therefore, the entirety of my CBP would not need to be involved in sending signals to my toes. Some subsystem must be involved in this process. In this case, I would still feel as though *I* wiggled my toes. The wiggling of my toes did not just happen to me. Suppose now that this subsystem that initiated my toe wiggling is very small. Now suppose that it is even smaller. How small can it get before toe wiggling is just something that is happening to me. There is no obvious size limit. We cannot just assume that quantum-level processes within our CBPs are things that are happening to me us opposed to things that we are doing.

Recall the sense of the term *authorship* and the sense of the term *control* that Balaguer is using. We have authorship and control over what we intentionally choose if and only if we cause our choices to occur, and nothing external to ourselves influences the choice at the moment the choice is finalized. This definition seems adequate for the notion of *authorship*, but we generally use the word *control* in a more robust sense. Control generally involves a guiding influence. Balaguer's theory of L-freedom, however, involves a more robust sense of control that he did not fully utilize. In a torn decision, we have control over our options in the sense that our reasons, desires, and beliefs guide and constrain which options we come to consider. Therefore we can have L-freedom, if we *author* the outcome of a torn decision, and we *control* which options we consider in the first place.

Nothing external to a quantum-level system can influence what state the system will collapse to at the moment of collapsing. Therefore, there is no sense in which the agent could have authorship of the collapse if the agent is something external to the quantum-level system. However, the quantum-level system in question here is internal to the agent. It is a tiny constituent of the CBP, and therefore, it is a tiny constituent of the agent. Therefore, by Balaguer's use of the term *authorship*, there is a tiny piece of the agent that *authors* the outcome of a torn decision. The only thing we know for certain about the collapse of a wave function is that it is not determined by anything external to the quantum system that the wave function represents, and it is not determined by any quantifiable, local variables internal to the system.

We should consider, however, whether this is the sense of control that we experience ourselves to have over our torn decisions. In order to explore whether this is what we experience, I will conduct an experiment. I can only introspect into my own experiences, so readers will have to do the experiment for themselves in order to determine whether they agree with my description of the experience. Clear your mind, and lift either your right arm or your left arm. When I do this experiment, I feel as though I am actively limiting myself to these two options. I feel as though I am making a decision, and I feel as though nothing external to my consciousness is influencing my decision. I feel as though my decision is somewhat random in the sense that I do not have any overriding desire to lift one arm instead of the other, but it is not random in the sense that something other than myself determines which arm I will raise. Metaphorically speaking, I feel as though I am flipping a coin, but I am forced to decide which side the coin will land on. This experience does seem to include only the types of authorship and control that we have specified as necessary for L-freedom. Therefore, if these are the types of authorship and control that I actually have, then my experience is veridical. If you do not agree with my description of this experience, then feel free to disagree with me on whether these are the types of authorship and control that we need for L-freedom. There is no way to argue for an objective claim about how everyone feels when doing this experiment.

We have determined the decisive wave function collapse would have to occur at the moment of choice in order to leave open the possibility of a veridical libertarian experience. Furthermore, the collapse would have to *underlie* our experience of making the choice in order for the experience to be accurately representing how the choice is made. The collapse would have to *underlie* the experience in the sense that the collapse would be a necessary constituent of the set of physical processes that are identical to the experience of making a torn decision. If the decisive wave function collapse were not a constituent of the set of physical processes identical to this experience, then the experience of indeterminism in the decision would not accurately represent an indeterministic physical process, and therefore, this experience would not be veridical.

To most readers, these conclusions will seem absurd and may even be considered reasons to assume that we do not have a veridical libertarian experience. I must confess that these conclusions do not seem absurd to me. Recall, however, that my main thesis here is: if our libertarian experiences are veridical, physicalism is true, and the Orthodox interpretation is correct, then at least some of our choices are finalized by wave function collapses, and such a collapse is the physical mechanism underlying the feeling of making the final decision. Regardless of how absurd the consequent of this thesis may seem, we still have reason to believe that this conditional statement is true.

In other words, I conclude that the following set of premises is inconsistent:

1. We have libertarian experiences.
2. Our libertarian experiences are veridical.
3. Mental states are identical to physical brain states.
4. The Orthodox interpretation of quantum mechanics is correct.
5. The collapse of a wave function does not underlie the experience of making a torn decision.

We have seen that if premises 1-4 are true, then premise 5 is false. At least one of these premises must be rejected. The question of whether to reject premise 3 may be impossible to empirically determine. We could reject premise 1. We could take the position that we do not actually have experiences of libertarian free will, instead our experiences are consistent with compatibilist descriptions of our experiences of free will. We simply experience that we are able to do the things that we want to do, after deliberating over various possible options, without being hindered by any form of coercion or mental instability. We do not feel as though we could choose either option holding fixed the history of the universe and the laws of physics. After enough deliberation, there is one option that seems more attractive to us and that is the option we choose, and if there is not one option that seems more attractive, then we will somehow choose randomly without any indeterministic sense of authorship.

Alternatively, we could reject premise 2. We could assume that we do experience that we have libertarian free will, but these experiences do not accurately represent reality. If this is the case, then one is led to wonder why we would be so deceived about our decision-making process. Do we gain some evolutionary advantage from feeling as though we are making the final decision, or is this feeling just an evolutionary side effect of having a brain?

We could reject premise 3 and assume dualism. In this case, we would be assuming that our minds consist of some non-physical substance apart from our physical brains. Here, the internal workings of the mind would not have to adhere to the laws of physics. We could take an agent causation view in order to explain our libertarian experiences. Philosophers have been debating over the issue of dualism versus physicalism for a very long time, and currently, physicalism is the more popular view. Regardless, if readers are unwilling to reject the other premises, then they will have to consider rejecting premise 3.

We have explored our options, and I will leave it to the readers to reject whichever premise(s) they choose. Each of these possibilities we have considered seem absurd to various people. It does not seem as though we could quantify which of these possibilities is the most absurd. In conclusion, here is a summary of my additions to Balaguer's account of L-freedom. In order for indeterminacy to enhance authorship and control over a torn decision and allow for L-freedom, the following conditions must hold in the case of a torn decision. There must be a collapse of a wave function in the CBP that finalizes a torn decision. Also, this collapse of the wave function must underlie the momentary experience of finalizing a torn decision.

4 POSSIBLE OBJECTIONS

I will now consider objections that have been raised against Balaguer's theory and theories similar to Balaguer's.

4.1 The Disappearing Agent Objection

Pereboom argues that Balaguer's position is susceptible to the Disappearing Agent (DA) objection.

> DA objection: Consider a decision made in a context in which moral reasons favor one action, prudential reasons favor a distinct and incompatible action, and the net strength of these sets of reasons are in close competition. On an event-causal libertarian picture, the relevant causal conditions antecedent the decision—agent-involving—would leave it open whether the decision will occur, and the agent has no further causal role in determining whether it does. With the causal role of the antecedent events already given, whether the decision occurs is not settled by any causal factor involving agent. In fact, given the causal role of all causally relevant antecedent events, *nothing settles* whether the decision occurs. Thus, plausibly, on the event-causal libertarian picture, agents lack the control required for moral responsibility. (2012, 60-61)

This objection is basically a response to Balaguer's definition of TDW-indeterminism, in which he states that "the choice occurs without anything else being significantly causally relevant to which option is chosen" (Pereboom 2012, 78). Pereboom claims that if nothing causes the choice to occur, then the agent does not cause the choice to occur either, and therefore, the agent cannot control the choice.

Pereboom initially assumes that the agent is something external to the choice and is supposed to cause the choice to occur. However, if the physical mechanism which produces the choice occurs within the CBP, then this physical mechanism is internal to the experience of being an agent, where this experience constitutes the agent under my definition. If the agent includes at least the experience of being an agent, or a CBP, and the choice is finalized by a wave function collapse that is included within the CBP, then the choice is made indeterministically, and at the moment of choice, nothing external to the agent is causally relevant to which choice is made. The agent has selected the outcome of a torn decision in the case that a collapse within the CBP selects the outcome, as long as we can allow that a selection made by a piece of an agent qualifies as a selection made by the agent. We have already concluded that we cannot assume that a selection made by a piece of an agent does not qualify as a selection made by the agent. Therefore, by Balaguer's use of the term *authorship*, the agent authors this choice. We have already concluded that the agent has *control* over the choice, in the sense that the agent constrains the options under consideration. Therefore if this situation does actually occur at least sometimes and our uses of the terms *authorship* and *control* captures our experience of control over torn decisions, then this situation is sufficient for L-freedom.

Pereboom, however, argues that the agent does not have the control required for moral responsibility. Balaguer explicitly states that he is not attempting to account for moral responsibility. Balaguer states:

> I think that as of right now, there is no good reason to think there is even a fact of the matter as to whether moral responsibility is compatible with determinism. And because of this, I think there is no good reason to think that there's a fact of the matter about the answer to the moral responsibility question. (2010, 63)

This sort of free choice may not constitute the sort of free will that would provide moral responsibility. This sort of free choice, however, might explain why we have the phenomenal experience that we must make the final choice between options that are actually open to us.

4.2 Nahmias's Close Calls Objection

In his paper "Close Calls and The Confident Agent: Free Will, Deliberation, and Alternative Possibilities" (2006), Eddy Nahmias argues that having alternative possibilities open to us holding fixed the history of the universe and the laws of physics, which he calls the alternative possibilities condition, or "the AP condition," is not necessary for free will. He argues that it is only necessary that we have the capability to effectively deliberate over what we desire to do and the capability to control our actions in light of our decision, which he calls "the 'Deliberation and Control Condition' (DC) condition" (Nahmias 2006, 628). He claims that the AP condition only seems necessary for situations where, after deliberating over what to do, we still do not know what we want to do. He calls these situations "close calls," while Balaguer would call them torn decisions (Nahmias 2006, 630). He contrasts these situations with situations in which after deliberating, we feel confident about what we want to do and we then enact what we want to do (Nahmias 2006, 635).

Nahmias constructs a thought experiment, in which he asks the reader to imagine an agent that is perfectly confident. This agent is perfectly confident in the sense that she always knows what she wants to do after deliberating, though she does not necessarily know what she wants to do before deliberating, and she always does what she decided she wants to do (636-637). Therefore, her experiences do not satisfy the AP condition, because she never experiences close calls, or torn decisions. He points out that though she always reaches confidence about what she wants to do, she still feels as though she could have chosen an alternative possibility after she has made her decision (had she deliberated differently).

Also, she still feels as though she has other options for what she could do before she has finished deliberating over her options. Further, she feels that her deliberation affects what she will decide and what she will do (637).

Nahmias argues that her ability to deliberate over which option she wants to choose does not require that it is metaphysically possible for either option to occur holding fixed the past and the laws of physics. Her ability to deliberate only requires that she can imagine choosing either option (638). He argues that her ability to deliberate does not require that she believes that after she finishes deliberating, it will still be metaphysically possible for her to choose either option (639). Nahmias claims that when she looks back on a decision she has made and feels regret, she does not desire that she had chosen an alternative option holding fixed the past and the laws, instead she desires that the situation had been different, such that she had known more about the unchosen option (639-640). Nahmias also argues that if it were metaphysically possible that she could choose between more than one option after she has finished deliberating and come to a confident decision, then her freedom and control would be hindered by this possibility that she might act in a way contrary to her decision (638).

Nahmias concludes that since this imagined confident agent still intuitively seems to have free will and her experiences do not satisfy the AP condition, the AP condition is not necessary for free will (642). I agree with Nahmias that there is a sense in which this confident agent seems to have free will, namely in the sense the she is free to do what she wants to do. However, I will object that she is missing an aspect of our experience that still requires explanation, regardless of the freedom that she seems to have. It is true that her ability to deliberate only requires that she can imagine choosing either option under consideration. This does not entail, however, that she does not feel before or after deliberation as though it is metaphysically possible that she could do otherwise than what she decides that she wants to do. She may not bother trying to deliberate over what she should choose to do, if she does not believe that it is metaphysically possible for her to choose either option. If she does feel as though she still has metaphysically open options, then it is worth considering whether this feeling is veridical. The fact that the confident agent could in principle participate in the arm raising experiment and place herself in a torn decision is a phenomenon that requires an explanation. We do make torn decisions and the way in which we make them requires an explanation. For those that feel as I do that I have metaphysically open options at least in the case of torn decisions, we will still want to know if this is actually true.

I must confess, however, that the sense in which the confident agent does seem to have free will is an important sense of free will that needs to be explored. It is important that we understand whether or not this sense of free will is sufficient for moral responsibility. In lieu of discovering whether there are quantum indeterminacies that underlie our torn decisions, we need to know to what extent people are morally responsible regardless of this discovery.

4.3 The objection that perceivable quantum effects in the brain are not possible.

Some people argue that quantum indeterminacy simply could not have a perceivable effect on the brain or on decisions, because the brain is too warm, wet, and noisy. I will provide evidence suggesting that it is possible that quantum indeterminacy could have perceivable effects on the rest of the brain. Consider first that any voluntary action must initially involve at least one neuron in the brain sending information to other neurons. This information is generally encoded as certain characteristics of specific firing patterns. If a quantum-level event can cause a neuron to initiate some specific pattern of firing, then it may cause a change in the behavior of the brain overall.

There have not been any experiments done as of yet to determine whether or not a quantum-level event can initiate a certain firing pattern. However, many experiments have been done to determine the general behavior of a single neuron (Plesser and Tanaka 1997, 228). This behavior often seems stochastic, or random and spontaneous (Plesser and Tanaka 1997, 228). The behavior of a single neuron is not always predictable. This does not mean that it is necessarily indeterministic though. It may just be that we are unable to simultaneously measure all of the relevant factors at play. The data that scientists have gathered representing the behavior of a single neuron have allowed for the creation of mathematical models which closely fit this data (Destexhe et al. 1994, 195). These mathematical models can be used to predict the behavior of a neuron accurately to a certain degree.

There are two major types of models that are fitted to experimental data recorded from neurons, deterministic Hodgkin-Huxley models and indeterministic Markov models (Destexhe et al. 1994, 195). Markov models treat the opening and closing of ion channel gates as indeterministic processes, while Hodgkin-Huxley models describe the global characteristics of ion currents as deterministic processes. A gate of an ion channel generally consists of a small section of a larger protein molecule. It has been shown that the overall behavior of a neuron can be modeled more accurately by indeterministic Markov models than by deterministic Hodgkin-Huxley models (Destexhe et al. 1994, 196), which provides reason to believe that the opening and closing of ion channel gates is an inherently stochastic process.

If the opening or closing of a single ion channel could cause a switch in the firing pattern of a neuron and this neuron affects a larger system of neurons, then this single ion channel could affect the behavior of a larger system of neurons. If the opening or closing of a single ion channel is an indeterministic process, as assumed by Markov models, then a quantum-level event could affect the behavior of a larger system of neurons. In most cases, however, a large number of ion channels are activated together to generate a firing pattern. If this number is large enough, then the system will behave according to the deterministic laws of physics, which we would expect for any involuntary process. There may be some situations, though, where only a few ion channels open or close and change the behavior of the entire neuron, which then affects the behavior of surrounding neurons.

A view that is becoming more popular in neuroscience is the view that the brain exhibits self-organized criticality (Plenz and Niebur 2014, 2). A complex, nonlinear system exhibits self-organized criticality if the dynamics of the system and its immediate surroundings are situated such that the system constantly tends towards a critical state (Chialvo 2014, 44). A critical state is a metastable state nearby a transition to various qualitatively distinct states (Chialvo 2014, 43). In such a state, a small disturbance of the system can cause a quick jump to a qualitatively different state of the entire system (Jensen 1998, 3). Various theoretical predictions can be inferred from assuming that the brain exhibits self-organized criticality. Some of these theoretical predictions have been experimentally verified (Chialvo 2014, 49).

In order to better understand the concept of self-organized criticality, consider an example of a more simple physical system that is known to exhibit self-organized criticality. Consider an avalanche of sand falling down a hill. There is a critical value for the slope of the hill, above which an avalanche will ensue (Jensen 1998, 14). If the slope of the hill is extremely close to this critical value, then dropping only a few grains of sand onto the hill can initiate an avalanche (Jensen 1998, 14). In the case of brains, self-organized criticality would allow for an immediate response to very small sensory impulses such as being poked by a needle. It is still a mystery, however, whether the brain or some part of the brain might be close enough to a critical point that it would be sensitive to a quantum-level event.

Hodgkin-Huxley models of the activity of a network of neurons are nonlinear, and therefore, they are sensitive to small changes in initial conditions. These models can also exhibit multistability for certain parameter values (Cymbalyuk and Shilnikov 2005). Multistability allows there to be multiple different steady state behaviors that a neuron could end up with depending only on initial conditions. A small difference in initial conditions could mean a big difference in the firing pattern of the neuron (Cymbalyuk and Shilnikov 2005, 10587). These models are often nearby a critical state (a bifurcation point). When the bifurcation parameter of a multistable model is very close to a bifurcation point, a small, short burst of conductance can cause a neuron to switch between stable firing patterns. A smaller and shorter burst of conductance can be used to produce a switch as the parameter gets closer to the bifurcation point. Such a small burst of conductance could be caused by a single gated ion channel opening and then closing. Therefore, since we have reason to believe that the opening and closing of an ion channel is an indeterministic process, we have reason to believe that an indeterministic process could change the firing pattern of a neuron and thereby effect a larger system of neurons.

Heisenberg, one of the founding fathers of quantum physics, stated:

> There can be no doubt that the laws of quantum theory play a very important role in the biological phenomena. For instance, those specific quantum-theoretical forces that can be described only inaccurately by the concept of chemical valency are essential for the understanding of the big organic molecules and their various geometrical patterns; the experiments on biological mutations produced by radiation show both the relevance of the statistical quantum-theoretical laws and the existence of amplifying mechanisms. The close analogy between the working of our nervous system and the functioning of modern electronic computers stresses again the importance of single elementary processes in the living organism. (Heisenberg 1958a, 104)

5 POSSIBLE NEUROSCIENTIFIC ACCOUNTS OF TDW-INDETERMINISM

I will now describe a couple of examples of neuroscientific theories of how a wave function collapse could be the deciding factor in a torn decision, and I will consider whether they satisfy the criteria for the veridical experience of L-freedom. I will not argue that either of these theories is correct or necessary to explain a veridical libertarian experience. I am just offering examples of how these decisive wave function collapses might be possible.

5.1 Stapp's Neuroscientific Account

Consider, first, the following non-controversial neuroscientific information. A synapse, where two neurons connect and communicate with one another, consists of a pre-synaptic side and a post-synaptic side. The signal sent through the synapse runs from the pre-synaptic side to the post-synaptic side. The pre-synaptic side is called a terminal (Kandel et al. 2013, 269). The signal runs across a neuron until it reaches the terminal, where the signal then initiates the opening of channels through the membrane. There is a voltage threshold for the opening of the gates on the calcium ion channels. These opened channels allow calcium ions to flow into the pre-synaptic neuron by diffusion. Neurotransmitters are stored in small sacs, called vesicles, in the terminal. The calcium ions entering the cell react with proteins attached to the vesicles causing them to release the neurotransmitters into the region between the presynaptic neuron and the postsynaptic neuron (Kandel et al. 2013, 278). Certain places along the calcium ion channels can be as narrow as about one nanometer, and the ionic diameter of a calcium ion can be approximated to be around 0.2 nanometers (Malasics et al. 2009, 2473-2474). This process of neurotransmitter release is called exocytosis (Kandel et al. 2013, 272).

Henry Stapp offers a quantum mechanical description of the process of exocytosis, adhering to the Orthodox interpretation. He claims, using the Uncertainty Principle, that the uncertainty of the lateral velocity is limited by the narrowness of the calcium ion channel, and due to the uncertainty principle, the uncertainty of the final lateral position of the ion becomes much larger (Stapp 2011, 30). Therefore, the wave function of the calcium ion becomes spread out over a larger area. The target site that needs to be reached in order to react with the relevant proteins is only a small section of this larger area occupied by the wave function (Stapp 2011, 30). Therefore, due to the narrowness of the calcium ion channel, there is a low probability that a single calcium ion will reach the target site. Considering all of the calcium ions that will cross through the ion channel and possibly hit the target site, the probability that the vesicle will be released is still significantly less than 100% (Stapp 2011, 31). According to Stapp (2011), this uncertainty in whether the neurotransmitters are released or not entails that the quantum state of the terminal is a "quantum mixture" of the state of being released and the state of not being released (31).

The dynamical effects of the release of neurotransmitters into a synapse are extremely nonlinear. The release the neurotransmitters would cause the postsynaptic neuron to fire which may cause a chain reaction throughout the surrounding network of neurons. The system may behave qualitatively differently depending on whether the neurotransmitters are released or not released. Through interactions with surrounding neurons, the two possible states of this system could correspond to two qualitatively different states of the entire brain (Stapp 2011, 31). Stapp states:

> The validity of the classical approximation certainly cannot be proved under these conditions, and in view of the extreme nonlinearity of the neural dynamics, any claim that the large effects of the uncertainty principle at the synaptic level can never lead to quantum mixtures of macroscopically different states cannot be rationally justified. (2011, 31-32)

Stapp claims further that an intentional action that a person is conscious of making would require a pattern of activity that lasts on the order of 10 milliseconds or 100 milliseconds (2011, 33). Therefore, the two different brain states that result from the release or non-release of certain neurotransmitters would have to be temporarily stable states that last on the order of at least 10 milliseconds in order to correspond to two different intentional actions (Stapp 2011, 33). Stapp claims that this can be achieved by the quantum zeno effect, which I will explain shortly.

Here, we should consider where Stapp suggests that the human will comes in to the picture. The only active role that consciousness takes in the Orthodox interpretation is the act of measurement. John von Neumann's formulation of the Orthodox interpretation holds that measurement by human beings forces the possible state of a quantum system to split into a collection of possible observable states (Stapp 2011, 24). Stapp assumes that the actual collapse into one of these possible observable states is "determined by 'nature'" (2011, 35). Therefore, Stapp concludes that the only active role consciousness could have in the brain is this process of forcing quantum systems within the brain into quantum mixtures of possible observable states (2011, 33–34). Stapp takes a dualist position on the mind-body problem in that he considers consciousness to be some immaterial substance that partitions matter into possible observable states (2006, 604-605).

Now, I will describe the quantum zeno effect. If one measures the position of a quantum particle, for example, an electron, the wave function of the electron will collapse onto a certain position. After some time has passed the wave function will spread back out over a larger area, but if one measures the position immediately after the first measurement, then with almost 100% probability, one will find the electron at the same position, and the wave function will collapse again. If one continues to very frequently measure the position of the electron, after an extended period of time, it will still almost definitely be at the same position. On the other hand, if one waits for that same period of time before making the second measurement, it will be much less likely that the electron will be in the same position (Griffiths 1995, 383).

Stapp suggests that when a signal reaches a terminal, consciousness partitions the number of possibilities for the terminal into either releasing the neurotransmitters or not releasing them. Nature then collapses the wave function representing these two possibilities onto only one of them. However, the wave function to diffuse back to an uncertain state before an action can be intentionally enacted, unless consciousness continues to partition the wave function into distinct observable possibilities for an extended period of time, because once one possibility has been chosen by nature, it will become extremely more likely to be chosen by nature immediately afterwards (Stapp 2011, 36).

5.2 Beck's Neuroscientific Account

Similar to Stapp, Beck focuses on the process of exocytosis, but they focus specifically on exocytosis in pyramidal cells in the cerebral cortex. He suggests that pyramidal cells play a primary role in attention (Beck 2001, 90). A single spike of signal reaching the terminal of the pyramidal cell will not cause the release of more than a single vesicle's contents (Beck 2001, 90). The release of the neurotransmitters contained in a single vesicle will generally cause only one spike of signal in the post-synaptic cell (Beck 2001, 90).

Beck calculates that quantum processes in the cortex last for time scales in the range from femtoseconds to picoseconds, or $1x10^{-15}$ seconds to $1x10^{-12}$ seconds, while macroscopic cellular processes last for time scales in the range from nanoseconds to milliseconds, or $1x10^{-9}$ seconds to $1x10^{-3}$ seconds. Physical processes in the cortex that endure for these shorter periods of time should be analyzed using quantum mechanics (101). These quantum processes include the electron transitions that are involved in the opening of the gates on the calcium ion channels. The voltage threshold for opening these gates corresponds also to an energy threshold. Beck suggests that when a signal reaches the terminal the energy increases to become near this threshold, but still below it (102). He proposes that this threshold might be breached by quantum tunneling, in which a wave function includes a state below the threshold and a state above the threshold and then collapses onto the state above the threshold (102). This wave function might represent an electron in the gate of an ion channel that transitions and causes the gate to open.

According to Beck, neural networks remain metastable so that they can quickly switch between behaviors when they need to (98). Beck claims that it is not necessary that quantum states cohere on a macroscopic time scale in order for a wave function collapse to cause observable behavior (108-109). He claims that due to the state of instability in the brain and the nonlinear dynamics at play, a quantum event could trigger a switch between different large-scale activities of a network (112). Beck claims that "because of the stochastic thermal background quantum action could only be effective in brain dynamics if it establishes itself as a 'quantum switch' within the microstructures" (98-99).

5.3 Would either of these accounts offer L-freedom?

There is no consensus in the neuroscience community yet as to whether either of these accounts might be accurate, but there is consensus that the release of the contents of a single vesicle into the synaptic cleft must be treated probabilistically. The probability of neurotransmitters being released in response to a single spike of signal ranges from 10% to 90% (Kandel et al. 2013, 270). Also, the probability of release is lower in the central nervous system (where voluntary behavior is encoded) than it is in the peripheral nervous system (where involuntary behavior is encoded) (Kandel et al. 2013, 270).

Consider first Stapp's theory. It does not immediately mesh with Balaguer's theory, because it is dualistic, while Balaguer's theory and my extension of it are physicalist. I would argue, however, that this neuroscientific account can be modified to adhere with physicalism. In Balaguer's theory and my own, we would consider the calcium ions under consideration to be constituent parts of consciousness. Stapp, on the other hand, assumes that consciousness is some nonphysical substance that is acting on these ions. He assumes that consciousness is acting on the calcium ions in a similar sense to the way consciousness acts on a quantum particle in an experimental setting, by observing it. It is unclear, however, how consciousness as a physical system, including the calcium ions under consideration, could observe something within itself. This might be possible, but we do not need to assume that this would have to be happening in order to salvage the majority of Stapp's theory. Instead of treating the partitioning of the wave function into a collection of possible states as an act of consciousness, we could treat the actual wave function collapse as an act of consciousness. Because the terminal is a piece of a physical system that is identical to consciousness, the indeterministic behavior of the terminal corresponds to the indeterministic behavior of consciousness. The quantum zeno effect could still be used to carry out an intentional action in such a scenario.

Beck argues, however, that the dynamics of an ion channel do not qualify to be treated as a quantum-level system (2001, 102), which implies that Stapp's application of the Uncertainty Principle in this case may not be valid. Regardless however, Stapp's use of the quantum zeno effect is interesting and worth exploring. The way in which he uses the quantum zeno effect might be applicable to other more plausible theories.

Beck does not offer an account of how the quantum process he describes would relate to the human will, though he insinuates that it does relate somehow (2001, 111-112). His neuroscientific account, however, could in principle offer TDW-indeterminism. If he is correct in concluding that the general flow of calcium ions through ion channels does not qualify for the classical approximation, then his account is preferable over Stapp's account. Again however, I am not advocating that either of these theories should be accepted as correct. These are simply examples of theories that have been proposed for how quantum effects might have large scale effects in the brain. Both of these examples are worth exploring and possibly testing.

6 CONCLUSION

In order for our libertarian experiences to be veridical, at least some of our decisions must be settled by a wave function collapse in the CBP. Also, this collapse must occur at the moment at which we experience finalizing the decision, and this collapse must underlie the momentary experience of finalizing a torn decision. If these conditions do not hold, then either we do not have veridical libertarian experiences, or mental states are not identical to brain states. Again, I will allow the readers to decide for themselves which option seems the most plausible.

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