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Three dimensions of time: An approach for reconciling the discrepancies between experienced time and modern physics

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Abstract

This essay reviews the discrepancies between the phenomenal experience of time and the characterization of time as it is currently conceptualized by modern physics. Three aspects of the subjective quality of time are identified: (1) the present is privileged and distinct from the past and future in that it is the exclusive time at which observers experience events as happening; (2) time flows from one moment to the next; and (3) the future is open and presents itself with genuine alternative possibilities. Strikingly, however, modern physics claims that these essential aspects of the experience of time are illusory products of consciousness. We argue that physics has dismissed aspects of experience that are sufficiently self-evident that they can reasonably be taken as axioms, and thus new frameworks that incorporate these elements should be considered. Towards this end, a framework is presented that characterizes the observer as a window moving through information space with three dimensions of time: objective time—corresponding to clock time; subjective time—the experience of the passage of time; and alternative time—the branching genuine possibilities presented by the future. This roughhewn framework illustrates the type of approach that could enable our scientific understanding of time to be brought into greater alignment with the essential ways in which we experience it.

Keywords

Alternative possibilities, dimensions, modern physics, phenomenal experience, time

Introduction

The passage of time is as paradoxical as it is inexorable. Remarkably, the manner in which we experience time is wholly different from how most modern physicists characterize it. From the vantage of phenomenal experience, the present is privileged. We can remember the past, and imagine the future, but we exclusively do so from the vantage of the present. Phenomenologically, time flows from the past to the future. "NOW" is always in the process of moving from one moment to the next. Finally, we experience the future as ripe with genuine alternative possibilities. The future feels open, and we feel the capacity to choose between real options. However, from the vantage of modern physics these fundamental aspects of the lived experience of time are considered illusory. There is nothing in physics that

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privileges the present. The current "NOW" in which we reside has no greater ontological existence than any other moment in time, past or future. Similarly, modern physics rejects the notion that time flows. As theoretical physicist Davies (2002) observes: "Nothing in known physics corresponds to the passage of time. Indeed, physicists insist that time doesn't flow at all; it merely is." Finally, from the perspective of physics the future is already set in stone. We are locked into a deterministic "block universe," where all future events already exist, like locations on a route we are inevitably fixed to travel.

In this essay, we explore the tension between time as it experienced and as it is currently characterized by modern physics. We argue that the disparities are so great that we should be cautious in favoring the current conclusions of the ever-developing field of physics, over the seemingly self-evident aspects of our lived experience. We argue that at a minimum, this disparity suggests the need for humility in our views regarding the nature of time, and the confidence with which we should accept its current characterization. Critically, we invite consideration of whether it might be possible to generate scientific approaches to time that better accommodate the manner in which we experience it. Towards this end, we review and expand on a multi-dimensional model of time (Schooler, 2015; Schooler et al., 2011) that offers an illustration of a possible way in which science might come to meaningfully account for the privileged present, the flow of time, and the existence of genuine alternative possibilities.

Opening Caveat

We must acknowledge at the outset that we are not physicists and that our characterization of how physics understands time is extracted from popular discussions of time by physicists such as Greene (2004) and Davies (2002). Furthermore, we are painfully aware of the many cases in which non-physicists co-opted certain claims and used them to promote what is sometimes referred to as "pseudo-physics." We sympathize with such concerns and recognize that some of the speculations that we will offer might be characterized in this manner. Nevertheless, we offer three observations in our defense. First, although our speculations later on in this essay may be unconventional, they are largely in keeping with those of Carr (2021, 2023), a respected physicist who trained with Stephen Hawking and published extensively on mainstream topics. Second, while our possible solution to the problem posed by the discrepancy between experience and current views of physics may be controversial, our characterization of the dilemma is defensibly grounded in mainstream physics and philosophy. Finally, we note that in addressing big questions such the nature of time, there are really two countervailing risks that must be considered: the risk of going outside of one's area of expertise and thereby introducing unreasonable speculations versus the risk of exclusively staying in one's area of training and thereby failing to tackle the discrepancy that differing perspectives on the matter pose. We suspect that a significant reason why people have been so complacent regarding the gulf between what modern physics claims about time and how it is experienced stems from people's reluctance to step out of their comfort zone. Physicists avoid thinking about the discrepancies between their claims and phenomenological experiences, following the oft cited retreat of "shut up and calculate." Psychological scientists fear to delve into the inconsistencies because they are intimidated by physics and do not want to get in over their heads. While such complacency may help to prevent overstated claims, it may also discourage people from acknowledging the elephant in the room: the claims of modern physics about time go directly against the most evident aspects of conscious experience.

Three Axioms of Experienced Time

Since the time of Euclid, it has been recognized that all logical frameworks must begin with a set of axioms, or first principles that are taken

as givens. By definition these initial axioms must be self-evident that is, they cannot be proven themselves but must be taken as manifestly apparent. As a consequence, the strength of a logical argument depends on how compelling one finds the axioms on which it is based. Because the axioms of an argument cannot themselves be proven, there is necessarily a degree of subjectivity to their selection. For example, one could logically assume that they are in a dream reality in which only they exist, and everything else is a mere figment. While solipsism is logically coherent, it is founded on an assumption that most of us find distasteful, and contrary to the manner in which we experience the world. Thus, most of us take as axiomatic that the physical universe exists outside of ourselves. Other axioms of existence that most of us take for granted are similarly grounded in subjective impression. For example, most of us assume that we really are conscious even though we cannot prove it scientifically and there are some (e.g. Graziano, 2013) who suggest it is an illusion. Most of us assume that other human beings are similarly conscious, although exactly how far down the phylogenetic tree we are prepared to ascribe consciousness (e.g. dogs, fish, insects, bacteria, plants) represents an assumption that varies quite substantially. Furthermore, as individuals we can vary in the certainty with which we hold certain assumptions. For example, we, the authors, are absolutely certain that we are conscious, virtually certain that all other humans are conscious, confident that all vertebrates and cephalopods are conscious, and are inclined to believe that insects are conscious but with somewhat less certainty.

The observation that people vary between one another in what axioms are taken as fundamental and the strength with which they hold their axioms pertains to our discussion in several ways. First, as will be elaborated later, individuals may vary in the degree to which they hold as axiomatic the self-evident aspects of personal experience versus those currently arising from modern physics. This variation allows most lay people to assume (based on their personal experience) that the flow of time is a fundamental aspect of reality, but leads most physicists to conclude (based on their science) that it is an illusion of consciousness. Second, it suggests that we can introduce axioms for which our certainty of their truth value may vary. For example, we, the authors, take both the existence of our consciousness and the existence of physical reality as axiomatic, but we are just a bit more confident in the former than the latter. This observation is important because in the following discussion we will outline what we take to be the three core axioms of experienced time (Figure 1). The axioms will be presented in order of decreasing certainty.

Axiom 1: It Is Always Now

An essential aspect of experience is that it occurs in a tightly delimited frame which we invariably take to be the present. Even if we are remembering the past or imagining the future we always experience doing so in the present. The observation that experience is always centered in the present, is essential to a variety of philosophical analyses including those of Kant (1998 [1781]), Heidegger (1962 [1927]), and Husserl (1964). However, we argue that this claim need not rely on deep philosophical analysis. It seems to be a simple brute fact of existence that consciousness always resides in the present, and it does so, regardless of the fidelity with which it is representing the specific details of the external world.

Axiom 2: Time Flows

A central aspect of the experience of the present is that it is intrinsically dynamic. We are always in the process of moving from one moment to the next, but never actually anchor on any particular moment. This intrinsic movement is central to the characterization of many astute philosophers of the experience of time including James' (1918 [1890]) notion of the stream of consciousness, Bergson's (1946) view of true time

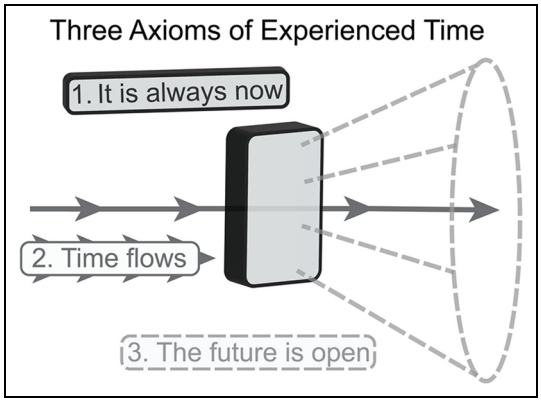

Figure 1. The three axioms of experienced time: (1) It is always now. This axiom asserts that all experience takes place in the present moment. "NOW" is depicted here as a temporally extended window (black). (2) Time flows from the past into the future. The flow of time is experienced in each moment blurring into the next (grey). (3) While the past is fixed, the future is open. There are many possibilities for what could happen in the future. The dashed cone (light grey) captures the tentative and open quality of multiple possible futures. The degree of shading depicts our certainty about each axiom where darker denotes greater certainty and lighter less, although we consider all three to be sufficiently certain to represent axioms of experience.

as an indivisible qualitative flow, and Whitehead's (1929) notion of process philosophy.

The ever-present now (Axiom 1) and the flow of time (Axiom 2) produce a corollary postulate: there is an essential "thickness" to now. "NOW" does not exist as an instant but rather spans some relatively brief period of time, what James (1918 [1890]) referred to as the "specious present," in which one moment evolves into the next. Critically, each evolving moment is itself in the process of flow. A useful metaphor is that of a flipbook in which one flips the pages and experiences a moving image. Consciousness never experiences the individual images in isolation but rather the movement from one image to the next. Accordingly, the present moment is necessarily temporally extended, we model the specious present as an observer window (Riddle & Schooler, 2024) that serves as the subjective vantage point.

Axiom 3: The Future Is Open

As we advance from one present moment to the next, one has the profound sense of being faced with genuine alternative possibilities and choosing between them. A core aspect of navigating life is making decisions between real options, both regarding the demands of the present and the more distant future. As Baumeister and Lau (this issue) observe "the essence of agency is operating in a situation with multiple alternative possibilities." With few exceptions (e.g. Harris, 2012) even those who advocate the notion that all of our choices are predetermined—tracking a single inexorable timeline of cause and effect—nevertheless acknowledge that it very much feels as if we are making genuine choices between real alternatives, that is, freewill. For example, Sapolsky (this issue) who unswervingly denies the existence of free will nevertheless concedes that "most thoughtful, reflective people believe that free will exists…. because acting on intent feels so palpably like free will that it becomes unimaginable that countless near invisible threads of the past generated that intent…"

The above three axioms seem to be absolutely fundamental to the way that we experience time and it is difficult to imagine thinking about time otherwise. Nevertheless, although all of them are above threshold for us as axioms of experience, we will concede that our confidence in them somewhat differs. It is extraordinarily difficult for us to conceive of how the present is not fundamentally privileged as the one and only period in which things happen. We understand that the present from one vantage may be different from that for another, but for any particular vantage there is a particular now and that now is when events unfold. The flow of time also seems to be self-evident although perhaps just a hair less so than the privileged nature of now. Mystics speak of experiences in which they allegedly realize that

the flow of time is an illusion. We suspect that what they mean is that they have the experience of stepping out of objective time, and that the flow of subjective time (see subsequent discussion) still marches on. However, the existence of such reports gives just a hint of pause regarding our absolute certainty in this assumption. Finally, the openness of possible futures strikes us as an assumption that is difficult to resist, but of the three it is the easiest to imagine that it could be wrong. It seems reasonable that there is only one future course of events that will actually come to pass (although see subsequent discussion of the Many Worlds interpretation of quantum physics in which there are multiple futures that are branching off but inaccessible to measurement or experience). If there is just one future that will happen, then plausibly there is only one future that could have ever happened. The absence of genuine alternative future possibilities feels like a major leap of faith but it is easier to imagine than the idea that the present is not uniquely privileged or that time does not flow. Although they vary somewhat in the absolute certainty with which we endorse them, the above three claims are all above threshold to represent axioms of experienced time. Which brings us to the next issue of what physics has to say about these claims.

Modern Physics Dismisses Experienced Time

As noted, it is a curious paradox that current views of physics explicitly dismiss the three axioms of experienced time, axioms which strike us as most self-evident. We briefly review why mainstream physicists challenge these seemingly axiomatic aspect of time and then turn to consider what to make of this disparity.

The Block Universe

A central aspect of the way that physicists conceptualize time arises from the fact that they typically "spatialize" it. That is, they attempt to place it on a similar footing to the traditional three dimensions of space. While time differs from a spatial dimension for all of the reasons described in the three axioms, the simple spatialization of time allows for physicists to run many useful computations and derive a working model to explain many natural phenomena. For example, time is a taken to be spatial in the prevailing Einstein–Minkowski interpretation of special relativity theory. The spatialization of time derives a "block universe" in which the traditional spatial dimensions are reduced (for purposes of visual illustration) to two dimensions from three, and time is added as a third dimension (Figure 2). Such a depiction can be thought of as a space-time "loaf of bread," where each narrow cross-section of the loaf, that is, "a slice," constitutes a moment in time.

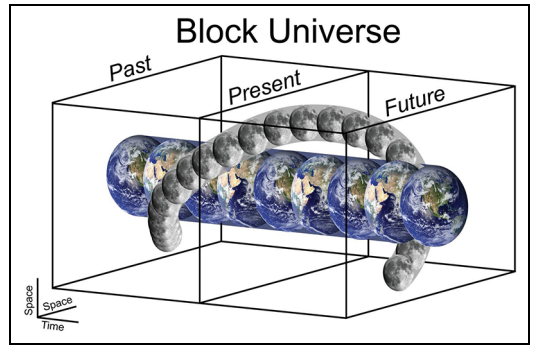

Figure 2. The block universe. Although the conventional view derived from experience is that the present is real and moves through time, current views in physics say this is erroneous. According to the standard block universe view in physics, all moments—past, present, and future—are equally real. The flow of time, the privileged present and the existence of genuine alternative futures are seen as illusions of consciousness. The progression through time of the moon orbiting the Earth is depicted as a series of time steps where there is nothing unique about the past, present, or future.

The Illusion of the Privileged Now

According to the block universe depiction of time, all slices—past, present, and future—already exist. As a result, the seemingly specialness of the present is viewed as illusory. Events do not happen

in the present. In fact, according to this view, events do not happen at all. Events are simply a location in the block universe, and there is nothing that privileges the present over any other moment in time. As Einstein observed, "The past, present and future are only illusions, even if stubborn ones" (quoted in Hoffmann & Dukas, 1972, p. 258).

The Illusion of the Flow of Time

Viewing time from the perspective of the block universe leaves no room for the flow of time. Once we conceive of the temporal dimension as the equivalent of another spatial dimension, then there are not enough degrees of freedom for the observer to move in time; that is, movement requires a rate in time, but time in the block universe is already represented as a spatial dimension, and thus cannot also be used as the metric that establishes the rate of movement through time. As the physicist Davies (2002) puts it:

> But what meaning can be attached to the movement of time itself? Relative to what does it move? Whereas other types of motion relate one physical process to another, the putative flow of time relates time to itself. Posing the simple question "How fast does time pass?" exposes the absurdity of the very idea. The trivial answer "One second per second" tells us nothing at all. (p. 8)

The view that the flow of time is simply a product of subjective experience, leads Davies (2002) to state the current position in physics regarding the ontological reality of the flow of time: "From the fixed past to the tangible present to the undecided future, it feels as though time flows inexorably on. But that is an illusion" (p. 32).

The Illusion That the Future Is Open

The block universe also entirely rules out the notion that the future is open. If every event can be derived from its causal determinants in the immediate past, then the existence of genuine alternative possibilities is eliminated. From the vantage of the block universe, all events—past present and future—already exist. There are no genuine options other than the one that is taken. Thus, a critical fallout of the view that the universe is deterministic (above the scale of quantum mechanics) and that the past, present and future already exist is that every choice we face is already locked in. Our experience that the future holds genuine alternative possibilities is simply an illusion of the limited vantage that we have regarding the topography of the block universe.

We acknowledged at the outset that we are not physicists, and readers at this point may feel tempted to dismiss our characterization of the block universe and its implications for dismissing the privileged present, the flow of time, and the existence of genuine alternative future possibilities. So, we invite readers to look into these claims for yourself. You will find that while there are some renegade physicists who question the current conceptualization of the fixed block universe (e.g. Carr, 2021; Penrose, 1989; Smolin, 2013), the prevailing view is that the seemingly most self-evident aspects of our experience of time are illusory products of consciousness. The aspects of quantum mechanics that appear to break determinism and challenge the block universe are explained away as only making an impact at the subatomic scale and determinism washes out all of the subtleties of the quantum foam (Tegmark, 2000a, 2000b). Indeed, at a public lecture co-author, Jonathan, once asked the noted physicist Brian Greene how he reconciled static view of nature in physics with the self-evidently dynamic experience of consciousness. He jokingly replied that he "sees a psychiatrist," asserting that consciousness is capable of all sorts of illusions, and that the flow of time is just another example of the artifacts of consciousness.

Consciousness as Fundamental, Not Incidental

It seems that current views of deterministic physics within a block universe leave no room for the most self-evident aspects of the experience of time. There is nothing special about the

present, as every moment past, present and future already exist. There is no way to move through time, as nothing can move within a fixed block. And, the existence of genuine alternatives is eliminated as the future is already locked in. It is as if modern physics has given us a pendulum clock but left us no room for the pendulum to swing.

Many physicists' approach to reconciling the differences between the experience of time and how they model it in their theories is to simply dismiss the seemingly self-evident aspects of time as illusions of consciousness. However, it is actually not evident how consciousness could exist in a block universe. As noted, arguably essential aspects of consciousness are that it is intrinsically dynamic and necessarily extended in at least a brief span of time (the specious present). However, it is unclear how these aspects of consciousness could arise in a fixed block universe. Just as matter cannot exist without space to extend in, consciousness seems to requires the capacity to extend and move in time. If extension and movement in time are ruled out by the block universe, then this might very well preclude the occurrence of consciousness in the first place, thereby necessarily preventing it from generating even the illusion of a privileged present, the flow of time, or genuine possibilities.

Even if it is possible that consciousness is somehow capable of illusorily generating the axioms of experienced time, it is far from clear, that this should be our default assumption. Typically, the decision to prioritize the conclusions of science over the conclusions of experience seems warranted. The sun and stars may seem to revolve around the earth but science tells us otherwise. However, we argue there are some situations where we should be wary of accepting the prevailing view of science over our own experience. As an illustration, imagine that based on the latest understanding of consciousness, scientists devised a consciousness detecting machine. They administer the machine to you and provide you with the unfortunate news: you think you are conscious but you are mistaken. Your belief that you are conscious is merely an illusion. Would you accept this conclusion? Although some might (e.g. Dennett, 1993, Graziano, 2013), we suspect that many of us would be wary, as our certainty in the reality of our own experience would outweigh our confidence in the science that led to the development of the consciousness detector. Scientific knowledge is constantly evolving, such that what is believed to be true at one time can be dismissed at another. At the turn of the 20th century, it was widely thought that Newtonian theory would be able to account for all of physics. Soon thereafter however this view was wholly overturned by the introduction of relativity theory and quantum mechanics. More recently dark matter and dark energy have fundamentally changed our view of what the universe is composed of. In this context, we should be cautious to rule out the seemingly most self-evident aspects of our experience of time based on the current state of science. At a very minimum, it suggests that we should keep an open mind to the possibility that new approaches to conceptualizing time may emerge that may be more compatible with our experience of it.

We maintain that a humble stance regarding the nature of time is justified not only by the observation that science routinely undergoes major revolutions, but also by the fact that although time and consciousness are intimately related we truly have no idea of how consciousness relates to the physical universe (the so called "hard problem of consciousness," Chalmers, 1996). As the award-winning physicist Linde (1990) observed: "Will it not turn out, with the further development of science, that the study of the universe and the study of consciousness are inseparably linked, and that ultimate progress in the one will be impossible without progress in the other?" (p. 27). Chalmers (1996), the eminent philosopher and coiner of the phrase "the hard problem of consciousness" makes a similar point:

> I propose that conscious experience be considered a fundamental feature, irreducible to anything

> more basic. […] In the 19th century it turned out that electromagnetic phenomena could not be explained in terms of previously known principles. As a consequence, scientists introduced electromagnetic charge as a new fundamental entity and studied the associated fundamental laws. Similar reasoning should be applied to consciousness. If existing fundamental theories cannot encompass it, then something new is required. (p. 96).

Accordingly, one key element of the approach that we are proposing is the suggestion that subjective experience be incorporated as an essential element of our model of reality. Although this may seem a radical suggestion, its reasonableness arises from the ontological certainty of one's own subjective experience relative to the only inferential certainty of physical reality. The view that consciousness represents a fundamental aspect of reality is a view that is advocated by (an albeit minority) of assorted respected physicists (e.g. Linde, 2004; Penrose & Hameroff, 2011; Stapp, 1993), philosophers (Chalmers, 1996; Goff, 2019; Strawson, 2008), neuroscientists (Koch, 2013; Tononi, 2008), and cognitive scientists (Hoffman, 2008, Kastrup, 2019). Indeed, Integrated Information Theory (Tononi, 2008), one of the leading scientific theories of consciousness (but see, Lau, 2023), takes as its initial axiom that consciousness is a product of integrated information, such that any time integrated information arises in the physical universe so too does consciousness.

Three Dimensions of Time

Combining the need to find a place for consciousness in models of reality with the lack of degrees of freedom in the standard block universe to allow for the privileged present, the flow of time, or genuine alternatives leads to an intriguing possibility. Perhaps, we need to postulate the existence of additional dimensions of time in order to provide the degrees of freedom necessary to allow the observer to move through objective time. As the physicist Carr (2021) observes "there is a link between the experience of time and the existence of higher dimensions." He justifies this conjecture with the very same argument that one of us has proffered before (Schooler, 2015; Schooler et al., 2011) namely that "… the apparent flow of time can only be described from a higher dimensional perspective, since from a 4-dimensional perspective one is bound to conclude that it is an illusion created by the mind."

Others similarly proposed that the postulation of additional dimensions of time may be key to reconciling the disparities between experienced time and physicists' current account of it (e.g. Broad, 1923, 1953; Price, 2011; Smythies, 2003, 2012). For example, the renowned physicist Linde (2004) observed:

> Is it possible that consciousness, like space-time, has its own intrinsic degrees of freedom, and that neglecting these will lead to a description of the universe that is fundamentally incomplete? What if our perceptions are as real (or maybe, in a certain sense, are even more real) than material objects? What if my red, my blue, my pain, are really existing objects, not merely reflections of the really existing material world? Is it possible to introduce a 'space of elements of consciousness….? (p. 451).

Although the postulation of additional temporal dimensions is unconventional, it is not unprecedented. Notably, string theorist have proposed the existence of an additional seven spatial dimensions (Greene, 2004). If additional spatial dimensions are possible, then it seems at least plausible that additional temporal dimensions might be possible as well. Clearly, we should be cautious in speculations as major as postulating additional dimensions of time, or even more controversially the notion that such dimensions might relate to something as elusive as consciousness. However, if the result of such conjectures is the opportunity to find a possible way to accommodate several of the most evident aspects of lived experience, then it seems worth at least entertaining them.

Although a fully explicated version with respect to physics of the perspective we are imagining would be well beyond our capacity, the

basic framework is reasonably straightforward, and one that we are hopeful the reader will find intuitive. The central notion is that conscious experience can be thought of as an observer window processing information through time where time is defined by three dimensions: objective time, subjective time, and alternative time. We briefly describe each dimension and then discuss how observer windows may move through these different time dimensions.

Objective time requires the least explanation because it corresponds to our standard notion of time, as measured by clocks, and is the time dimension of the block universe. Objective time is the universal reference frame upon which all clocks are calibrated (although we are aware of the added complication when considering warped space-time in general relativity).

Subjective time corresponds to the experience of the passage of time, as in when time seems to pass slowly or quickly relative to objective clock time. Assorted factors can influence our movement in subjective time relative to objective time. When in deep concentration, subjective time can pass very quickly relative to objective time, leading to "time contraction." By contrast, when in a life-threatening situation, subjective time can pass quite slowly ("time dilation"), enabling a car accident to seemingly unfold in slow motion. Notably, from the vantage of the experiencer, subjective time is as real, if not more real than objective time. The value of experience is meted out over subjective time not objective time. The allure of positive experience and the aversiveness of negative experiences does not depends on how much time they actually take but rather on how much time we experienced them to take.

In all likelihood the relationship between objective time and subjective time varies across species. The observer windows of smaller animals may move faster in subjective time relative to objective time than that of larger animals. This possibility is supported by research looking at cross-species comparisons of flicker fusion—the rate at which a flickering light is experienced as continuous. The maximum rate that a light can flicker before it is experienced as continuous can be viewed as a metric of the passage of subjective time relative to objective time; that is, the faster the flicker fusion rate, the greater the movement in subjective time relative to objective time. Animals can be trained to distinguish between the experience of flickering versus continuous light displays, and using this approach Healy et al. (2013) found that on average smaller animals tend to have a faster flicker-fusion rates than larger animals. This may be why it is so difficult to swat a fly—from the vantage of the fly we are moving in slow motion.

Analysis of the electrical activity of the brain reveals a tight correlation between its rhythmic fluctuations and the time course of subjective experience. In the Nested Observer Windows (NOW) Model (Riddle & Schooler, 2024), we propose that the manner in which a system experiences time is determined by its biological infrastructure. In the NOW Model, the temporal extension of the observer window in objective time is directly related to the brain's ability to sustain synchronized electrical activity through time. On average, larger biological structures exhibit slower activity patterns and process information at a slower time constant than smaller structures. As a result, the flow of subjective time within larger systems will correspond to that slower rate of information processing. The NOW Model further proposes that there are nested biological structures with an increasingly faster rate of processing at the lower (smaller) substructures. Your subjective experience corresponds to the observer window at the apex of the nested hierarchy (see Figure 3b). However, you experience a confluence of time signatures in the information content of consciousness as information in your nested subwindows bubbles up the hierarchy and reaches your awareness.

Alternative time corresponds to the notion of branching timelines. As noted, at every moment it certainly seems as if there are alternative instantiations of the next moment that present themselves to us as genuine possibilities. The

idea of alternate timelines runs against the standard version of the block universe because there is a deterministic change from one moment in time to the next. Admittedly in modern physics, quantum states appear to exist in a state of superposition in which none are truly manifested until a measurement is taken on the system, whereby one of the variety of potential states is realized. However, this "collapse of the wave function" from multiple possibilities to a single reality is generally presumed to only be relevant at the most microscopic scale of reality. Accordingly, at the scale at which humans and the physical world operate it is generally assumed that (as noted earlier) determinism washes out all of the subtleties of the quantum foam (Tegmark, 2000a, 2000b).

There is, however, one controversial but still increasingly considered interpretation of quantum physics that does postulate branching time lines. One of the deep challenges in quantum mechanics is explaining why the act of observation appears to collapse the probability cloud of alternative outcomes. Quantum states appear to exist in a state of superimposition in which none are truly manifested until the observer takes a measurement, whereby one of the variety of potential states is realized. This is illustrated by Schrödinger's (1983) famous thought experiment in which a cat is placed in a sealed box along with a mechanism that has a 50% chance of releasing poison based on the decay of a radioactive atom. According to the principles of quantum mechanics, as long as the box remains closed, the cat is considered to be simultaneously both alive and dead. Opening the box either decisively kills or spares the cat. There is no single currently accepted account of how the act of measurement appears to collapse the wave function, but one increasingly considered notion is known as the Many Worlds interpretation (MWI) (Everett, 1957). According to this view, all possible outcomes of quantum measurements are physically realized, each in a different, branching "world" or universe. In other words, this view suggest that there is no collapse of the probability cloud of alternatives, rather the universe is constantly diverging off into different time lines. In the context of Schrödinger's cat experiment, the MWI suggests that the measurement is associated with branching universes: one where the investigator finds a live cat and another in which they find a dead one. The MWI thus leads to the postulation of constantly separating time lines. According to this view, all possible outcomes are physically realized, each in a different, newly distinguished "world" or universe. Although seemingly outlandish, the MWI is increasingly becoming a mainstream account of quantum effects, and considered by some to be the most compelling way of understanding its many curiosities (e.g. Deutsch, 1997).

We find the MWI highly implausible. Indeed, by postulating that the universe is constantly branching off into different universes at every movement of every electron, atom, and photon, it could well be the least parsimonious theory ever conceived! Nevertheless, we favor the MWI's conjecture that there exist genuine alternative timelines in which an observer may find themselves from one moment to the next. However, rather than assuming that the observer is constantly simultaneously splintering off into multiple alternative universes with different versions of the observer in each one, we posit that at each choice point the observer takes *just one* of an assortment of possible vectors in the alternative time dimension. This view is akin to the view that consciousness collapses the wave function by Stapp (1993) and the Orchestrated Objective Reduction model by Penrose and Hameroff (2011). These theories speculate that somehow biology found a way to magnify subtle quantum effects to the scale relevant to neural processing (see recent advances in quantum biology [Engel et al., 2007] and quantum computer technology [Arute et al., 2019]). We are agnostic as to the particular mechanism, but suggest that the postulation that biological systems are able to navigate between the options of an alternative time dimension provides a way of conceptualizing how such systems can encounter multiple genuine alternative

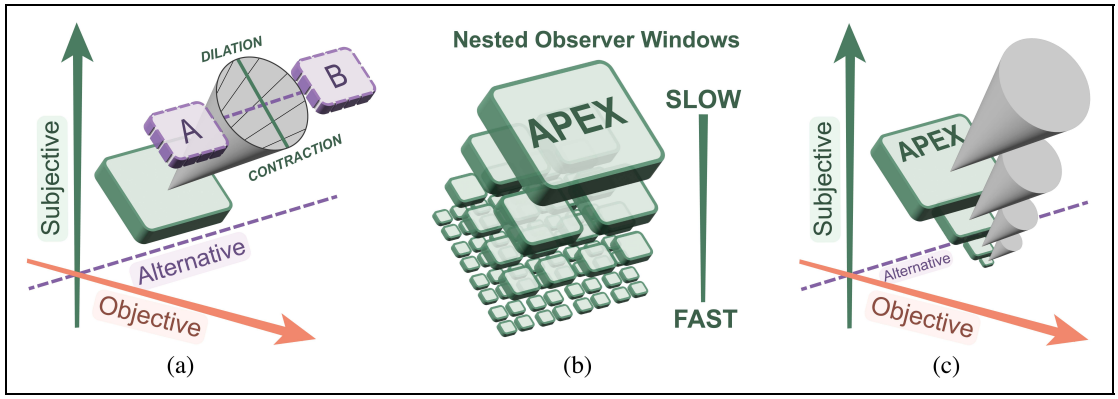

Figure 3. The three dimensions of time. Experienced time can be visualized in three-dimensions: (a) the observer window is viewed as moving forward along objective time (orange). The experienced speed of subjective time is along the vertical axis (green): *a shallower angle* causes time to fly by and *a steeper angle* causes time to dilate and slow. To the left and right are alternative timelines that can be selected (purple). (b) The Nested Observer Windows (NOW) Model suggests that the brain comprises nested hierarchically organized structures that process information. Each level is a mosaic of the lower levels as information is passed up the hierarchy. Movement in subjective time is proportional to the processing speed of the observer window relative to objective time. (c) In the NOW Model, smaller faster observer windows precede bigger slower observer windows but are encompassed by them (larger cones begins later but overtake the smaller ones).

possibilities while only following a single time line.

One appeal of the three dimensions of time framework is that it naturally lends itself to spatial visualization. There are a variety of ways of spatializing the framework, and indeed we encourage interested readers to play around with the model for themselves. However, one way to imagine it is as follows. Imagine a 3-dimensional space where forward corresponds to objective time, vertical corresponds to subjective time and horizontal corresponds to alternative time (Figure 3a). The shape of the space can be further imagined as a forward facing cone, like a light cone in physics. The cone can be intuitively understood as a forward movement through time where the shallowness or steepness of the slope represents the speed of subjective movement. A shallow slope is a contraction of conscious experience as if time was flying by, for example, when day dreaming, and a steep slope is a dilation of experience as if time was moving slowly, for example, in a life-threatening situation. If the observer window goes exclusively forward, with no vertical movement, then no subjective experience occurs at all (as in anesthesia). Hypothetically, if the frame goes exclusively up it would be experienced as if objective time stood still. Left and right repre-sents choice, for example, we are faced with two paths and must choose the left or the right path.

In the Nested Observer Windows (NOW) Model, the rate of movement through subjective time relative to objective time is determined by the biological infrastructure of the observer window (Figure 3b). Similar to smaller organisms, smaller observer windows move faster in subjective time relative to objective time, for example, neuron, relative to larger observer windows, for example, functional brain regions. When visualizing the NOW Model in three dimensions of time, typical experience will be characterized by smaller and faster observer windows moving through objective time ahead of the larger slower observer windows. However, the larger slower observer windows make larger movements through objective time that encompass the trajectories of the smaller windows (Figure 3c).

This very basic framework provides a potential way of conceptualizing how subjective observers might navigate through time. Because there is now a subjective dimension of time, it becomes meaningful to speak of the flow of time as the movement of an observer window in subjective time relative to objective time. Similarly, the privileged present can be defined as the location of a moving observer window in the three dimensions, and critically as the juncture where one of the alternative possibilities of the future becomes realized as the single actuality of the present. Consciousness is modeled as an observer window with temporal extension in both the subjective and objective time dimensions. Finally, freewill can be built into the model as the capacity of an observer window to shift in the alternative time dimension.

The inclusion of Nested Observer Windows into the model introduces a host of additional potential advantages. First it connects the three dimensions of time framework with a biologically plausible model (Riddle & Schooler, 2024) of conceptualizing how the brain may be composed of a nested hierarchy of conscious agents each "NOWing" at their own rate. In this manner, it also builds on Carr's (2021, 2023) notion that there may exist systems with different sized specious presents, with the larger specious presents circumscribing the smaller ones. Multiple sized Observer Windows also provides a way of conceptualizing how larger windows may have a greater capacity to move in the alternative time dimension. Accordingly, as biological systems have evolved larger and larger Nested Observer Windows they may have acquired increasing capacity to navigate in the alternative time dimension. In this way, physicists may have generally failed to notice the importance of possibilities, but by the time we get to human life, possibilities are everywhere.

Closing Remarks

Notably, even if the additional dimensions of time that we propose cannot be established as genuine dimensions of physical reality, they still represent meaningful dimensions of psychological reality. No matter what physics has to say on the matter, phenomenologically each one of us finds ourselves as a window moving through an information space that can be reasonably characterized as being defined by three dimensions of time. There is of course no question that we experience objective time as we go through our days. It is as undeniable as it is inexorable. Subjective time is equally indisputable, and indeed in many ways it is more important to us than objective time. Ultimately, what matters most to us is not how much time actually passes but how much time we experience passing. Finally, alternative time is the branching of possibilities that we experience every day as we face decisions. It corresponds to the timeline we followed and all those we might have followed but did not. By analogy, the compatibilist approach (e.g. Dennett, 2003) to freewill argues that it is possible to view freewill as psychologically real because, regardless of the underpinning deterministic metaphysics, people experience real choices and undergo genuine decision-making with their choices. Similarly, even if we reside in a deterministic fixed block universe, we decidedly experience the passage of time and the facing of real possibilities, so developing models that accommodate this psychological reality seems a worthy endeavor.

Many physicists suggest that we should dismiss the essential aspects of our experience of time as illusory because physics has no way to explain them. However, this seems very much equivalent to insisting that we treat consciousness itself as illusion, as science similarly has no way of explaining it. As noted at the outset, all logical endeavors must select the axioms from which they begin. Many physicists have taken their current theories of time as space to be axiomatic and from that basis dismissed the seemingly most self-evident aspects of phenomenal experience. This is a defensible perspective; people are entitled to develop their logical edifice based on the axioms that they find most compelling. However, *what is not defensible is to argue that this is the only defensible*

perspective. Given how compelling the privileged present, the flow of time, and the existence of genuine possibilities are to our lived experience, it seems entirely justifiable to insist that these elements be built into the foundation of our logical understanding of reality. From this vantage, theories that dismiss these self-evident aspects of experienced time are incomplete and need to be reformulated. The three dimensions of time framework outlined here represent one such effort; starting with the essential elements of the lived experience of time, and providing a framework that conceptualizes the movement through time from the vantage of the observer.

A reasonable question regarding the proposed framework is how might it be tested? This is of course an important question and one deserving of serious consideration. We note however that as a first step it would be of genuine value to consider whether the model can be further specified and mathematically formalized in a manner that can accommodate extant findings. Notably many theories are of value even if they do not currently lend themselves to strict empirical validation. Simply identifying a scientifically workable framework that enables us to avoid dismissing as illusory our most self-evident aspects of experience seems justification enough, but if empirical tests of the framework emerge, as they might from further specification, all the better. The approach that we have outlined here is roughhewn and is offered merely as a pointer to the type of model that might be able to more naturally accommodate our core aspects of experienced time. At a minimum, it provides a visual representation of ways of thinking about the central aspects of the manner in which consciousness resides in and moves through time. Perhaps it will inspire others to consider how our scientific understanding of time can be brought into greater alignment with the essential ways in which we experience it.

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