THE MANY-FACETED ENIGMA OF TIME: A PHYSICIST'S PERSPECTIVE

Bernard Carr *

Introduction

The problem of time is essentially interdisciplinary, involving an overlap between physics, psychology, neuroscience, philosophy and theology. In all these domains, it represents an enigma, as indicated by the following quotes. Feynman (physicist): "We physicists work with time every day but don't ask me what it is. It is too difficult." Whitehead (philosopher): "It is impossible to meditate on time without overwhelming emotion at the limitation of human intelligence." St Augustine (theologian): "What is time? If no one asks me, I know. If I wish to explain it to one that asked, I know not."

In this talk I will be speaking in my capacity as a physicist, but I will also emphasize that physics may need to expand to address issues usually regarded as being in the other domains. Part I will describe the mainstream physics view of time, as it arises in Newtonian theory, relativity theory and quantum theory. I will also discuss the various arrows of time and the (less understood) role of time in quantum cosmology, quantum gravity and higher-dimensional models. Part II will address the most challenging enigma - the passage of time associated with consciousness. I will argue that this goes beyond both relativity theory and quantum theory, so that one needs some new physical paradigm to accommodate it. I present my own (very speculative) proposal for such a paradigm, this invoking higher dimensions and touching upon other controversial topics covered at this meeting.

Various books have influenced me in preparing this talk. As regards the role of time in physics, three important ones are *The End of Time* (Barbour 2001), *From Eternity to Here* (Carroll 2010) and *Time Reborn*

* Queen Mary, University of London, UK.

(Smolin 2013). None of these mentions consciousness but this topic is covered in more recent books, such as *The Singular Universe and the Reality of Time* (Unger & Smolin 2015), *What Makes Time Special* (Callender 2017) and *The Order of Time* (Rovelli 2018). The link with philosophy is described in *Time's Arrow and the Archimedes' Point* (Price 1996) and the link with neuroscience in *Your Brain is a Time Machine* (Buonomano 2017).

Part 1: Mainstream physics perspective

The measurement of time

All clocks depends on the laws of physics, so development in physics have led to ever more accurate time pieces. The first ones - water clocks (3000 BC) and sundials (1500 BC) - depended on very simple physical laws. Later ones - mechanical clocks (1300), portable spring clocks (1450) and pendulum clocks (1657) - depended on more technical laws. The degree of precision culminated with Harrison's sea clock (1735), developed to measure longitude, and mass-production soon gave rise to shelf clocks (1807) and miniaturized watches (1854). Developments in atomic physics then led to quartz clocks (1928) and cesium clocks (1948). The dates (in parentheses) are taken from Whitrow (1972). Strontium atomic clocks have now reached an accuracy 10^{-18}, so time can be measured more accurately than space. There are also natural clocks resulting from radioactive decay and these cover a huge range of time scales: uranium-lead dating of rocks (4.6 billion to 1 million years), potassium-argon dating of clays (4 billion to 100,000 years), uranium-thorium dating of corals and fossilized bones (700,000 to 10,000 years), and carbon-14 dating of organic remains (100,000 to 10,000 years).

Time in classical physics

The arena of Newtonian physics is 3-dimensional space and time, both of which are absolute (i.e. the same for all observers). Newton's paradigm is also mechanistic, in the sense that the future and past are implicit in present. This is emphasized by Pierre Laplace: "An intellect which at a certain moment would know all the forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies in the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes." So this was the start of a trend in physics for time (i.e. the present moment) to become incidental rather than fundamental.

The arena of Einstein's special relativity (SR) is 4-dimensional spacetime, with objects being described by worldlines. Photons travel at 45 degrees in a spacetime diagram, so the observer's visual field at any moment corresponds to part of his past light-cone. Time is still different from space, because the 4D distance in the time direction is imaginary in the mathematical sense, but there is no absolute present and moving clocks run slow. This is demonstrated by observations of cosmic ray muons. These travel at 0.9994c and decay in 2 x10^{-6} s in their own frame, so should travel only 600m from the edge of the atmosphere. However, they decay in 0.06 s in the Earth's rest frame, which allows them to reach the ground. The time dilation effect also gives rise to the twin paradox, in which the twin who travels at high speed ages much less than one who stays still. There might appear to be a paradox because velocity is relative, so either twin might be regarded as moving, but it is the twin who accelerates and decelerates who is younger.

Time is more complicated in general relativity (GR) because spacetime is curved by gravity, which affects both space and time measurements. This means there are many individual times, with the duration experienced depending on the space-time path. Clocks run slow in a gravitational field, with objects falling to where time is slowed, and the longest duration is experienced by a freely-falling observer (e.g. an astronaut in orbit). For example, one's head ages more than one's feet by 300 nanosec in 80 years (because the gravitational field is smaller at a greater distance from the centre of the Earth) and someone living in bungalow for a year is a microsecond younger than someone living at the top of a skyscraper. The combination of the SR and GR effect on time has been tested by flying atomic clocks on planes (Hafele & Keating 1972): those going eastwards record 40 nanosec less than a clock on Earth because the speed effect wins; those going westwards record 273 nanosec more because the height effect wins.

Black holes and time travel

The effect of gravity on clocks is most pronounced for a black hole, a region formed when an object undergoes gravitational collapse and falls within its event horizon radius $R_{EH} = 2GM/c^2$ (just 3km for the Sun). Light can never escape from such a region because the light-cones tilt inwards inside this radius, with an 'outgoing' light-ray coinciding with the event horizon. Time stops at edge of a black hole, in the sense that an infalling astronaut appears to freeze there for an external observer. However, time continues to pass in the astronaut's own experience and he may see the whole future of our Universe while falling towards the central singularity.

The slowing down of time due to either SR or GR allows an astronaut to effectively travel into the future. Indeed, he can travel arbitrarily far into the future relative to someone on Earth by hovering close to black hole but not falling inside it. However, time travel into the past is more challenging. In SR it would require tachyons (i.e. objects moving faster than light), which is probably precluded. However, it may be possible in GR because of the existence of solutions with closed timelike curves (CTCs). For example, CTCs arise in a rotating universe (Godel 1949) or they can be generated by a rotating cylinder (Tipler 1974). One can also travel into the past through a wormhole (WH) - different from a black hole because there is no singularity - but only back to a time *after* it was created (Thorne 1994). It is not clear that this is physically realistic since one needs negative energy to hold the WH mouth open and the Chronology Protection Conjecture (Hawking 1992) suggests that time machines are excluded. However, this is not certain and WHs may have been created in early Universe.

Time in quantum theory

Quantum theory (QT) is associated with various enigmas (e.g. the two-slit experiment, Schrodinger's cat, the Uncertainty Principle, entanglement) and has various interpretations (e.g. the Copenhagen, Pilot Wave, Many Worlds and Transactional models). These are discussed by Sheehan and Cyrus (2022), so I will only focus on the issue of time here. Whereas time is fuzzy in GR, it is more Newtonian in QT - in the sense that one needs a preferred spatial hypersurface to explain entanglement - and space is fuzzy instead (corresponding to non-locality). Indeed, time may emerge from the irreversible interaction between the micro-quantum objects and the macro-classical objects that make measurements (Connes & Rovelli 1994). Entanglement may even *generate* time (Page & Wootters 1983). Since QT is limited to isolated systems, the existence of clocks and outside observers requires a deeper theory extendable to the whole Universe. As discussed later, there is also the issue of whether consciousness collapses the quantum wave function (Wigner 1967) and this relates to the nature of time at least indirectly.

Arrows of time and the big bang

There are many arrows of time, each corresponding to some form of past/future asymmetry: cause and effect, birth and death, the cosmic expansion, retarded rather than advanced radiation, quantum collapse. The puzzle is that the laws of fundamental physics are time-reversible apart from a tiny charge-parity (CP) violation. There is also the psychological arrow, associated with consciousness; this is more problematic than the others and will be addressed later. It is often argued that all these arrows arise from 2nd Law of Thermodynamics: entropy is always increasing because the environment is far from equilibrium. Eddington (1928) remarked: "If your pet theory of the Universe is in disagreement with Maxwell's theory, so much the worse for Maxwell's theory. If it is found to be contradicted by observations - well, these experimentalists do bungle things sometimes. But if your theory is found to be against the 2nd Law of Thermodynamics, I can give you no hope; there is nothing for it but to collapse in deepest humiliation."

The most natural explanation for the increase of entropy is that the Universe began in a low-entropy state (the Past Hypothesis), although the reason for this is not well understood. Most cosmologists believe that the Universe began in a highly compressed state (termed the 'Big Bang') around 14 billion years ago, so this raises the issue of the origin of time. This is a topic of long-standing controversy. Aristotle thought there could be no beginning of time, whereas St Augustine argued that God created time with the Universe, but of course neither knew about the Big Bang. Until a few decades ago it was assumed that physics would break down at the Big Bang but recent developments in physics have changed this perspective, so this leads onto the next topic.

Time in quantum cosmology and quantum gravity

According to Hawking (1966), the Big Bang corresponds to a singularity of infinite density. Classical physics breaks down then, so one needs a theory of quantum cosmology (QC) to understand what happens to time. It is sometimes argued that there can be no time in QC because time requires an external observer and there is nothing outside the Universe. However, according to Hartle and Hawking (1983), time becomes imaginary (i.e. like space) at the Planck time (10^{-43}s after Big Bang), corresponding to what they term the 'No Boundary' proposal. Alternatively, the Universe may have undergone an earlier collapsing phase, corresponding to a 'Big Bounce', and one could even have a cyclic model with successive expansion and contraction phases (Tolman 1934).

QC also relates to quantum gravity (QG), which has important implications even when the density is finite. QG effects imply that space and time become granular rather than continuous on the Planck scales (10^{-33}cm or 10^{-43}s), corresponding to some form of spacetime foam (Wheeler 1955). This raises the question of whether space and time are fundamental in QG or just emergent features of the macroworld. There are different views on this, since there are many approaches to QG. Canonical QG implies there is no time (DeWitt 1967) but Causal Set Theory allows the passage of time for localized observers (Sorkin 1991). String Theory suggests the 'final' theory will be like QT (with space being fuzzy), whereas Loop Quantum Gravity suggests it will be like GR (with time being fuzzy). While this might seem the logical endpoint of the history of physics, this having progressively diminished the role of time, Smolin (2013) argues that it is real and a key to understanding QG. In his view, when physics is extended to the whole Universe, laws must emerge and evolve with Universe.

Time in higher dimensional theories

An understanding of all the forces which operate in the Universe suggests that there are extra 'internal' dimensions beyond the four of spacetime. This approach was pioneered in the 1920s with the suggestion that a fifth dimension can provide a unified description of gravity and electromagnetism (Kaluza 1921) if it is wrapped up on the Planck scale of 10^{-33}cm (Klein 1926). Subsequently, it was discovered that there are other subatomic interactions and recent unification theories suggest that these can be explained by invoking yet more wrapped-up dimensions, superstring theory suggesting there could be six (Green et al. 1987). There were originally five superstring theories but it was later realized that these are all parts of a single more embracing model called 'M-theory', which has seven extra dimensions (Witten 1995). These developments are illustrated in Figure 1(a).

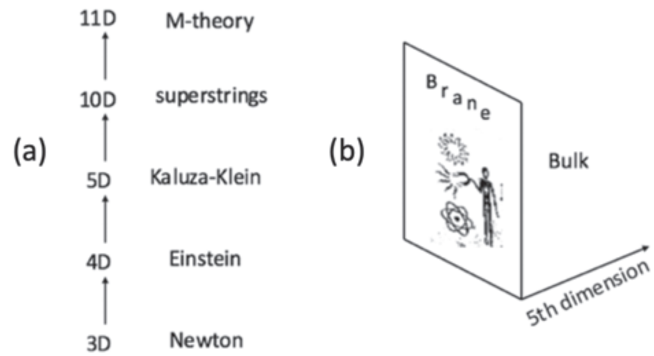

Figure 1. (a) Sequence of dimensional shifts entailed in the unification of physics. (b) The extra dimensions are often assumed to be compactified but one is extended in brane theory.

Although the extra dimensions are usually assumed to be compactified on the string scale (somewhat above the Planck scale), in some models they can be much larger (Arkani-Hamed et al. 2000) and in one variant the fifth dimension is extended, so that the physical world is viewed as a 4-dimensional 'brane' in a higher-dimensional 'bulk' (Randall & Sundrum 1999). This is illustrated in Figure 1(b). The extra dimensions are usually assumed to be spacelike but they may be timelike in some models and this has crucial implications for the discussion below.

Part 2: Extended physics perspective

Time and consciousness

Physics has been triumphant in explaining the multitude of structures in the material world, from the smallest scales of subatomic physics to the scale of the observable Universe. It has also explained and unified the forces which connect the micro and macro domains. Physicists even claim to be close to a 'Theory of Everything'. However, one might be sceptical of this claim when their model makes no reference to the most conspicuous aspect of the world - consciousness and the domain of mind. Indeed, despite the current interest in mindfulness, current physics might be regarded as depicting the triumph of mindlessness.

It is sometimes argued that consciousness and mental experiences are necessarily outside the domain of physics because they involve a 1st person rather than 3rd person perspective. Clearly this is true for classical mechanistic physics but this has now been superseded by the quantum physics and there are hints that consciousness may be important in this context - either because it collapses the wave-function (Stapp 1993) or because the collapse of the wave function generates consciousness via microtubules (Hameroff & Penrose 2014). However, this does not explain mentality, so one probably needs some deeper paradigm that underlies both consciousness and quantum theory. This may also describe the *flow* of time, which is related to the psychological arrow but deeper than a mere arrow (see below).

In considering whether some future paradigm of physics can accommodate consciousness, it must be stressed that the current paradigm is certainly incomplete, since we still need to amalgamate quantum theory and relativity theory and we cannot preclude this involving consciousness in some way. Penrose (1989) anticipates that "our present picture of physical reality is due for a grand shake-up, even greater, perhaps, than that provided by present-day relativity and quantum mechanics". Just as relativity theory links space and time, and quantum theory links matter and mind, perhaps there is also some unification of matter, mind, space and time, as illustrated in Figure 2.

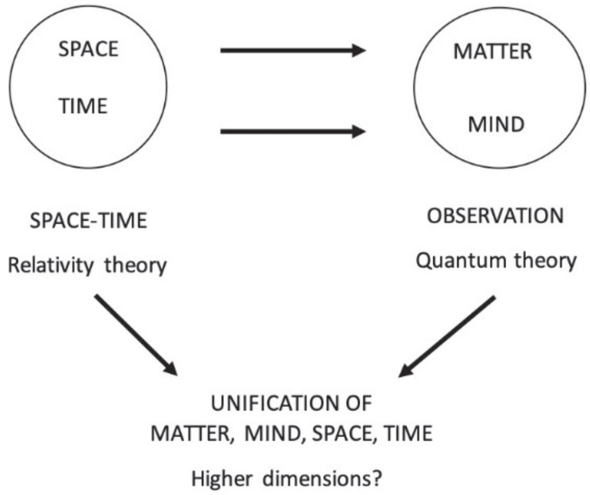

Figure 2. The amalgamation of space and time by relativity theory and of matter and mind by quantum theory suggests a deeper amalgamation of matter, mind, space and time.

My own approach to such a unification is based on the idea that many mental experiences involve some sort of space, albeit distinct from physical space (Carr 2015). The phenomenal space associated with normal physical perception is an obvious example of this and philosophers have long argued about its relationship to physical space (Russell 1948). The traditional view is that the percept is localised within the brain, so that phenomenal space is just an internal mapping of physical space, with a separate one for each observer. However, this results from the outdated view that the arena of reality is 3-dimensional space (S_3). According to relativity theory, the arena of reality is 4-dimensional (4D) spacetime (S_4), so perception is a 4D process, with the brain just being one end of a causal chain. So physical perception corresponds to a sort of extended mind (cf. Velmans 2005), in which conscious experience at any time is associated with the parts of spacetime linked to the brain through a causal nexus of signalling world-lines. The edge of the nexus corresponds to the past light-cone, since no signal can travel faster than light. This is represented in Figure 3(a) and termed the 'outlook tree' by Culbertson (1976).

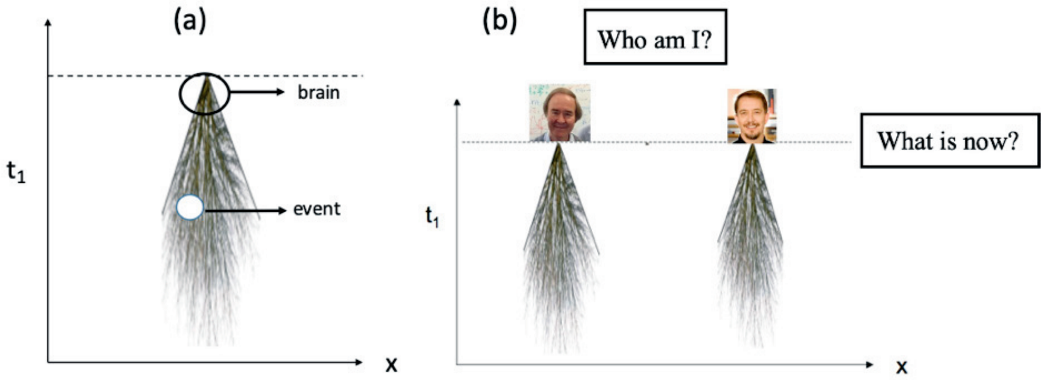

Figure 3. (a) 4D model in which phenomenal space is associated with the space-time region connected to the brain via a nexus of signalling world-lines. (b) Illustrating the link between the problem of identity and the problem of the passage of time.

Note that the nexus is very concentrated near the top because it also represents all the neuronal processes involved in perception. The mapping between physical and phenomenal space is therefore complicated and not just a geometrical projection. Also a more sophisticated 'informational' model would be required to accommodate qualia. This also has interesting implications for the nature of memory. The mainstream view is that memories are stored in the brain, but if percepts are not there, the same must apply to our memories of those percepts. Indeed, Figure 3(a) suggests that memories of physical events reflect the direct access of consciousness to the physical space-time which contains those events. In this case, the brain contains a *tag* rather than a *trace*.

This model raises two questions, both of which will be explored in subsequent sections. The first relates to the passage of time (*What is now?*) and the second to the problem of identity (*Who am I?*). As indicated in Figure 3(b), these questions are closely related. I will also argue that they both have a link with physics, although my proposal certainly does not represent the mainstream view of physicists.

The passage of time

A long-standing problem on the interface of physics and philosophy concerns the flow of time. The point is that relativity theory does not describe the basic experience of 'now' which is such an essential ingredient of our perceptual world. For in the 'block' universe of special relativity, past and present and future coexist. The 3D object is just the 'constant-time' cross-section of a 4D world-tube and we come across events as our field of consciousness sweeps through the block. However, nothing within the space-time picture describes this sweeping or identifies the particular moment at which we make our observations. So if one regards consciousness as moving along the world-line of the brain, like a bead on a wire, as illustrated in Figure 4(a), that motion itself cannot be described by relativity theory.

This is illustrated by two famous quotes. The first is from Weyl (1949): "The objective world *is*, it does not *happen*. Only to the gaze of my consciousness, crawling upward along the life-line of my body, does a section of this world come to life as a fleeting image in space which changes in time." The second is from Einstein's letter to the family of Michele Besso, shortly after his death in 1955: "Now he has departed from this strange world a little ahead of me. That means nothing. People like us, who believe in physics, know that the distinction between past, present and future is only stubbornly persistent illusion".

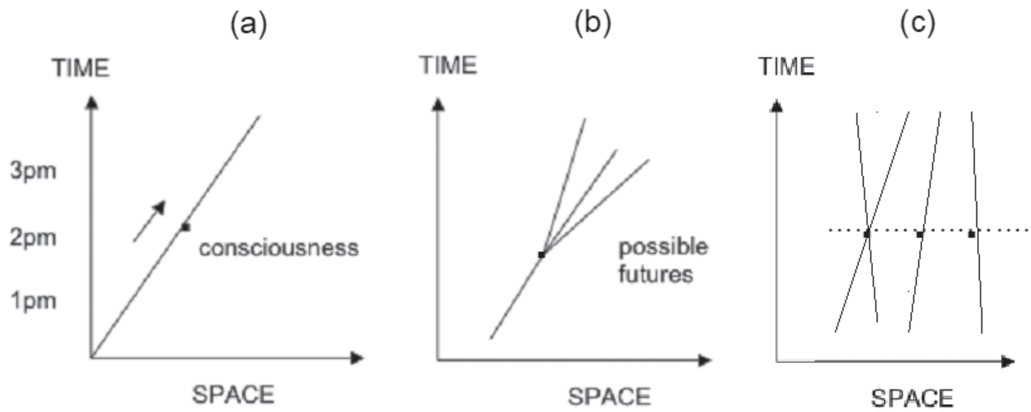

Figure 4. Three problems of consciousness from a relativistic perspective: (a) passage of time, (b) selection of possible futures, (c) coordination of time for spatially separated observers.

This also relates to the problem of free will. In a mechanistic Universe, a physical object (such as an observer's body) is usually assumed to have a well-defined future world-line. However, one intuitively imagines that at any particular experiential time there are a number of possible future world-lines, as illustrated in Figure 4(b), with the intervention of consciousness allowing the selection of one of these. The middle line in the figure shows the unchanged (mechanistic) future, while the other lines show two alternative (changed) futures. This view implies that the past is fixed but that the future is undetermined.

Thus there is a fundamental distinction between *physical* time (associated with relativity and the outer world) and *mental* time (associated with the experience of now and the inner world). Many people have made this point (Broad 1923, Eddington 1928, Brain 1960, Lockwood 1989) and it was the focus of a famous debate between Einstein and Bergson almost exactly a century ago (Canales 2019). Indeed, there is a huge philosophical literature on this topic and an ongoing controversy between the presentists and eternalists (Savitt 2006). Since the passage of time seems to give no extra *physical* information, many philosophers infer that this passage is unreal and just a feature of mind (McTaggart 1908, Putnam 1967, Price 1996). But some philosophers (e.g. Maudlin 2012) and physicists (e.g. Smolin 2013) still believe time is fundamental and this possibility is accentuated if the final theory of physics can accommodate consciousness.

Another question which arises is how the 'beads' of different observers are correlated. If two observers interact (i.e. if their worldlines cross), they must presumably be conscious at the same time (i.e. their 'beads' must traverse the intersection point together). However, what about observers whose worldlines do not intersect? Naively identifying contemporaneous beads by taking a constant time slice, as illustrated by the broken line in Figure 4(c), might appear to be inconsistent with SR, since this rejects the notion of simultaneity at different points in space. On the other hand, the notion of a preferred time is restored in GR because the large-scale structure of the Universe singles out a special 'cosmic time' measured by clocks comoving with the cosmic expansion. There are preferred spatial hypersurfaces with constant proper time since the Big Bang (Ellis 2006).

The failure of relativity to describe the passage of time process and different possible future world-lines may also relate to QT? This is because the collapse of the wave-function to one of a number of possible states entails a basic irreversibility. One way of resolving this is to invoke the 'many worlds' picture of Everett (1957), which is reminiscent of the representations in Figure 4(b). One also needs some concept of simultaneity at different points in space in QT? in order to describe the Einstein-Podolsky-Rosen (1935) paradox. The problem of reconciling relativity theory and quantum mechanics may thus connect to the problem of understanding consciousness.

5-Dimensional reality structure

One way of describing the passage of time - originally suggested by Broad (1923) - is to adopt a growing block universe model, together with a second type of time (t_2), or at least a higher dimension, with respect to which our motion through physical time (t_1) is measured. This is illustrated in Figure 5(a), which represents the progress of consciousness as a path in a 5-dimensional (5D) space. At any moment in t_2, a physical object will have either a unique future worldline (in a mechanistic model) or a number of possible worldlines (in a quantum model). The intervention of consciousness or quantum collapse allows the future worldline to change in the first case or to be selected from in the second case. Since the future is not predetermined in this model, there is an intrinsic difference between the past and the future (Earman 2008).

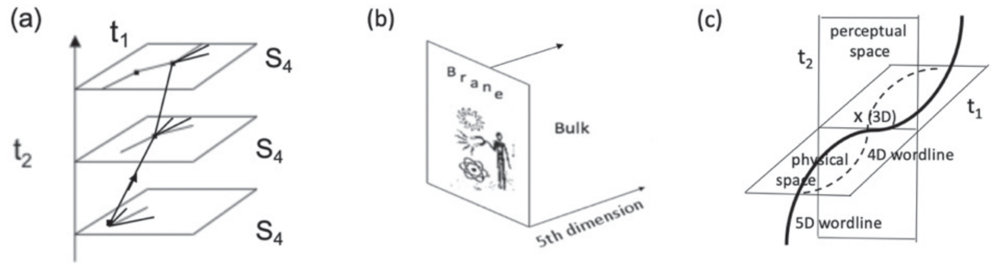

Figure 5. (a) Describing passage of time with a second time dimension. (b) Comparison with brane cosmology. (c) Depicting a unified 5D psychophysical space with 3D phenomenal and physical spaces having distinct times.

This interpretation of the flow of time may also be suggested by the Randall-Sundrum proposal that spacetime is a 4D brane embedded in a 5D bulk. In the simplest case, the brane corresponds to the flat spacetime of SR. However, there is a cosmological version of this picture - called ‘brane cosmology’ - in which the brane is curved and space is expanding

(Maartens 2004). The cosmic expansion can then be interpreted as being generated by the brane's motion through the 5th dimension, as illustrated in Figure 5(b). This suggests that the 5th dimension could be identified with the extra dimension associated with the passage of time (Carr 2021), thereby using a cosmological model to resolve a long-standing philosophical problem. Several physicists have also invoked two-time models (e.g. Bars 2001, Craig & Weinstein 2009). In particular, Aharanov et al. (2013) have presented a 'two-time' view of quantum evolution, in which each moment of time is viewed as a new 'universe'.

As illustrated in Figure 5(c), the implication of this model is that a complete description of perception must involve a 5D 'psycho-physical' space, with physical space-time (x,t_1) and phenomenal space-time (x,t_2) being different slices of (x,t_1,t_2) space (cf. Smythies 1994). There are two features of this proposal: phenomenal space is *collective* rather just inside our heads; one needs a separate time dimension to describe mental experience. Needless to say, this is very different from the view of mainstream physics and philosophy.

The specious present

The invocation of a second time dimension, as represented in Figure 5, only generates a *global* flow of time and does not describe the sense of individual identity (or 1st person perspective). This is because the *experience* of time - and hence consciousness itself - only makes sense with respect to the specious present (SP), which is the minimum timescale of experience. I will argue that this feature must play a crucial role in understanding the passage of time, although this point seems to be neglected by both physics and philosophy.

This concept of the SP was introduced a long time ago (Kelly 1882) but can be understood in modern times as arising because our physical sensory systems have a resolution time of order 0.1 second, so that we cannot observe a process shorter than this (Hertzog et al. 2016). For example, if a light source moves in a circle around some central point faster than around 10 times per second, then one just sees a continuous circle of light rather than motion. So in some sense time becomes like space on too short a timescale. There is a similar effect for all perceptual processes, whatever the sense mode, and it has been suggested that consciousness itself is associated with a brain-scanning process of 40Hz, which corresponds to a time of 0.025 s (Gold 1999). There is also an *upper* limit to the timescales we can experience since our brains are not aware of changes that are too slow. The upper limit on the timescale for human consciousness cannot be specified as precisely as the lower limit. Since the apprehension of change depends on a comparison of systems at different times, it probably relates to the timescale associated with short-term memory, which is around 10^3 s.

Although the SP is well determined during the usual waking state and roughly the same for everyone, it may change in some circumstances, so that the flow of internal time appears to speed up or slow down relative to external time. For example, in a circus, the SP becomes shorter for a trapeze artist, so that external time slows down and he can catch his partner. On the other hand, it becomes longer for a balance artist, so that external time speeds up and he can hold his pose. The change may be more dramatic in some circumstances. For example, time may slow almost to a halt during an accident (so that external events appear to freeze) or speed up during a fever (so that the rising and setting of the sun appear as a flickering light at the window). Presumably such variations can be described by neuronal processes if the brain has some internal clock whose rate may change. Indeed, there is a huge neuroscientific literature on time perception and its variability (Eagleman 2005).

Some reported changes in the SP are much more dramatic (Wittmann 2018). For example, in a Near Death Experience (NDE) one may see one's whole life 'instantaneously', corresponding to a SP exceeding one's lifetime. In certain mystical states, the changes in the SP may be even more extreme, sometimes shrinking almost to zero, so that only the present moment exists, or expanding almost to infinity, so that the entire history of the cosmos appears instantaneously. Ed Kelly (personal communication) points out a similarity between the description of mystical experiences produced through the stages of *samādhi* characterized by Patañjali and an early anatomist twisting the focus knob on his microscope: "It's as though the meditator is adjusting the focal length of his hyperphysical sensors and encountering systematically different worlds depending on the settings achieved." These states are described by Taimni (1961). It is not clear that these more dramatic SP variations can be explained in neurological terms. Indeed, this may suggest that consciousness can be decoupled from the brain in some situations, implying that the brain is a *filter* rather than a *generator* of consciousness (Bergson 1946).

The fact that we only experience consciousness over a few decades of time (0.1 - 10^3 s) is similar to our only perceiving electromagnetic radiation over the narrow range of frequencies associated with visible light. This suggests that there could be other forms of consciousness in the Universe - not necessarily associated with brains and perceiving the world through organs sensitive to a different frequency range - with a very different SP from humans (Royce 1901). Indeed, since complex physical structures exist over a vast range of scales, it is conceivable that these could also be associated with consciousness (i.e. contain memories and an internal model of the world). For example, if computers develop consciousness, perhaps they would have a SP of order nanoseconds and maybe there are extraterrestrial life-forms with a SP of a thousand times our own. If so, we would have to speed up the recording of their communications a thousand times to listen into any 'conversation'.

The SP notion can also be applied to the parapsychological phenomena of interest to some participants at this meeting. Thouless and Wiesner (1947) argue that the focus of the mind is usually the brain but that processes they term 'psi-gamma' (receptive) and 'psi-kappa' (expressive) can act on surrounding penumbra in space and time. If so, it is natural to hypothesize that the SP gives the scale of the penumbra. Indeed, one might argue that ESP corresponds to an increase in the SP and PK to a decrease. There is also a link with closed timelike loops (since there is no distinction between past and future on a timescale less than the SP), so this relates to the model of precognition presented by Mossbridge (2022).

The nature of self

The notion of the SP is also relevant to the problem of personal identity. Since one's identity is defined by the sequence of unique perspectives of the set of events provided by one's brain (i.e. one's memories), it must be associated with the nexus of spacetime connections shown in Figure 3(a). Clearly myself and Etzel Cardena (my chair) have different nexuses but why am I associated with one particular nexus. To illustrate this, imagine that myself and Etzel were born at exactly the same time in neighbouring beds in the same maternity ward. Our neurons start to fire and we become conscious simultaneously. So why does *my* self become associated with Bernard's body rather than Etzel's?

This question is particularly pressing for the filter model of consciousness. This suggests that mind is a unitary phenomenon, in that "there is one mind common to all individual men…a universal mind" (Emerson 1983), and it differentiates between individual consciousness (small c) and the universal Consciousness (big C) which is being filtered. But this raises the question of how Consciousness can fragment into billions of consciousnesses and why I am associated with one particular fragment. Expanding the nexus to higher dimensions, as in Figure 5, explains why many I's can be aspects of a single I, because worldlines which are disconnected in a lower-dimensional space may be connected in a higher-dimensional one, but not why I am me.

Of course, mainstream scientists will reject this question - and the filter model - at the outset, since it presupposes that there is some form self which is different from the brain. But if consciousness is produced by the brain, there can be no me distinct from the brain. However, the question of identity arises in any theory of consciousness and it is precisely because it is meaningless from the mainstream perspective that I am led to reject that perspective. The existence of an extra time dimension is also relevant. For since physical time t_1 and mental time t_2 are different, what does it mean to say that Etzel and I are conscious at the *same* time? We may both be conscious with respect to external time but 1st personhood presumably relates to internal time.

In addressing this problem, it must be appreciated that there can be no memories on a time scale less than the SP or more than a human lifetime. This implies the dissolution of human identity on both long and short timescales. This also arises in the *spatial* context. For if one were to view an object either on the scale of the interatomic spacing or on such a large scale that it could not be resolved, there would be no indication of a single coherent structure.

It is conceivable that the SP also relates to the higher dimensions of physics. In standard M-theory the extra dimensions are spatial and compactified on around the Planck scale. However, in principle the compactification scale could be much larger and we have seen that one dimension is extended in brane cosmology. One could also consider a model in which the extra dimensions are compactified on a hierarchy of scales and one might even speculate that each dimension is associated with a specious present. One would then have a hierarchy of levels of consciousness, associated with a hierarchy of time dimensions. Of course, this proposal is clearly very speculative and does not represent mainstream physics.

Final words

The above discussion - even the speculations in Part II - have mainly focussed on time and mentality as they relate to the physical world (i.e. phenomenal space and memory). I have stressed that this requires a paradigm going beyond relativity theory and quantum theory. In particular, I have advocated a 5-dimensional model, with the extra dimension relating to mental time and the specious present also playing an important role. A similar proposal, involving both these features, has been made by Schooler (2015). However, there are other forms of mental space, both normal (visualization space, dream space) and paranormal (apparitions, OBEs, NDEs). I have argued elsewhere (Carr 2008) that these might also be identified with the higher dimensional space of physics. But this proposal goes beyond the present discussion and is even more speculative, in the sense that most physicists would not accept the reality of the phenomena. Nevertheless, this illustrates how physics might in principle be extended to accommodate mind and some of the anomalous phenomena of interest at this meeting. This does not depend on the validity of M-theory itself (M-theorists would clearly be uncomfortable with this association) but it does require some form of higher-dimensional model.

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