The Quantum-Mechanical Frame of Reference

Part 2: Logical Type in Time Evolution

Andrew Soltau

Abstract: In Part 1 the solution to the measurement problem is shown to be logical type. The world encountered is a class-of-worlds-as-a-world, a domain in which the collapse dynamics operates in a clearly defined ontology. A further level of logical type resolves the paradoxes of special relativity, and reveals the full definition of transtemporal reality.

Given the static block universe of relativity, thus eternalism, the passage of time is an oxymoron. Equally, the Andromeda paradox means that presentism – only the present is real – cannot be correct. The solution is a moving frame of reference, a universal third-logical-type phenomenon which produces a system implementing both metaphysics of time. Effectively, on the inside view of the moving frame of reference, within the context of the block universe of eternalism, presentism is correct. The two great paradoxes of relativity are also resolved. The Now, the present moment that cannot exist in physics, is simply the contents of this moving frame of reference. The passage of time is the immanent effect. Phenomena impossible in the objective physical reality occur naturally.

The enactment of the quantum-mechanical dynamics is also explained. The quantum concept of time (Deutsch, 1997, ch. 11) is the static layout of all possible versions of the physical world, 'snapshots'. As the moving frame of reference passes from one to another, the collapse dynamics effectively operates: von Neumann's (1932) 'Process 1'. Everett's (1957) theory is the physics of this process. In effect, as he states, the standard formulation of quantum mechanics is enacted. Between observations, the linear dynamics operates as the frame of reference moves along the world line, within the context of a specific snapshot: 'Process 2'.

This also provides a complete and operational definition of the transtemporal individual: the sequence of states of the memory, sapience, experienced by the consciousness that supervenes on the moving frame of reference, sentience. The interaction of the two produces the perceiving subject missing from the physics. The world of such an individual is ipso facto the class-of-worlds-as-a-world described in Part 1.

1 Present & Eternal

> Spacetime is sometimes referred to as the 'block universe' because within it the whole of physical reality – past present and future – is laid out once and for all, frozen in a single four-dimensional block. (Deutsch, 1997, p. 268)

> In Einstein's physics, there is no passage of time, no unidirectional flow from the fixed past and toward the uncertain future. The temporal component of space-time is as static as its spatial components; physical time is as still as physical space. It is all laid out, the whole spread of events, in the tenseless four-dimensional space-time manifold. (Goldstein, 2005, p. 254)

> … the distinction between the past, present and future is only a stubbornly persistent illusion (Einstein, quoted in Dyson, 1979, p. 193)

This is eternalism. However, as Lucas comments on the block universe:

> It fails to account for the passage of time, the pre-eminence of the present, the directedness of time and the difference between the future and the past. (1989, p. 8)

That is why presentism has been considered: the past and the future do not exist, only the present moment. This, however, falls prey to the Andromeda paradox in which presentism is shown to be directly contradicted by relativity. This means that just changing the direction in which one is moving alters whether distant events happened some time ago, or have yet to happen. Given presentism, the observer who changes direction would be radically altering the physical state of affairs in the Andromeda galaxy, which physics obviously does not allow.

In the block universe there is no such problem. The observer is just changing what is true for that observer, in that particular, *relative* frame of reference. Naturally, this means that objectively both states of affairs are true 'all the time', i.e. they simply exist. All of existence is 'there', 'already'. This is the essence of the Rietdijk-Putnam-Penrose argument for the block universe, addressed in depth by Savitt (2017). But the block universe has the paradoxes of the passage of time, the absence of the pre-eminent present and so on. It seems this cannot be right either.

The solution is that both paradigms are true. All that is required is a moving frame of reference. This is a phenomenon that is to the moments in space-time as the film gate of the movie projector is to the frames of the movie film: the frame of reference is constantly moving from one moment to the next, along the world-line. This explains the *appearance* of the passage of time within the context of the static block universe. Thus effectively, on the inside view of this frame of reference, the world is a changing three-dimensional world, as is universally experienced. In this case both views are true: presentism is just the inside view of the objective reality of eternalism.

McTaggart (1908) famously held that time could not be real because two obviously correct descriptions of time, the A series and the B series, were mutually contradictory. The solution, however, is that both are indeed real. They are simply the properties of different types of frame of reference, in the same system. The A series is the succession of moments encountered as the moving frame of reference passes through space-time, along the four-dimensional world line. The static B series of moments is the sequence of events along which it moves, laid out in the relativistic block universe of the standard objective view, the 'view from nowhere'. The B series is the time of eternalism, and the A series is essentially presentism. Both views are correct.

2 The Train-Window Phenomenon

The problem is that a moving frame of reference of this nature cannot, by definition, be a physical phenomenon, and thus cannot be addressed in the framework of physics. Logical type (Russell, 1908) serves ideally to resolve the conundrum. The frames of a movie film are of a first, primitive, logical type, compared to the movie itself, the set of all the frames, which is of a second logical type. The movie projector is of a third logical type, operational on the set of all possible movies: the set of all possible sets of frames. It is an iterator mechanism that applies to all sequences of frames. It is necessarily contextual to any given sequence. Here the presence of the same three logical types, as fundamental operational levels of physical reality, is taken to be an unavoidable conclusion. Each moment along the world-line of an observer is of the first logical type. The world-line itself, the whole set of moments in sequence, is of second logical type. For such a sequence to be encountered, there is necessarily a third-logical-type phenomenon in operation.

The passage of time is of the logical type of the scenery in a train window. It appears that the countryside passes, but of course this is just the effect of the movement of the frame of reference. The field that is apparently passing by is in fact static: it is not going anywhere. In a logically identical manner, the moving frame of reference produces the appearance of the passage of time in the static relativistic universe.

This also naturally explains the great paradox of the present moment, the Now as Einstein dubbed it. As he stated, this distinction: “... does not and cannot occur within physics.” (Carnap, 1963, p. 37) which was a great worry. As Mermin explains:

> The issue for Einstein was not the famous revelation of relativity that whether or not two events in two different places happen at the same time can depend on your frame of reference. It was simply that physics seems to offer no way to identify the Now even at a single event in a single place, although a local present moment — Now — is evident to each and every one of us as undeniably real. How can there be no place in physics for something as obvious as that?

> My Now — my current state of affairs — is a special event for me while it is happening. I can tell my Now from earlier events, which I only remember, and from later events which I can only anticipate or imagine. The status of an event as my Now is transitory: it becomes a memory as subsequent Nows emerge.
>
> Yet clear, evident and banal as this is to us all, there is no Now in the usual physical description of space and time. Physicists represent all the events experienced by a single person as a line in four-dimensional space-time, called that person's 'world-line'. There is nothing about any point on my world-line that singles it out as my Now. (2014)

The moving frame of reference resolves this problem: it retrodicts exactly this phenomenon. The Now is simply the inside view of the moving frame of reference. This is the pre-eminent present missing from eternalism.

The appearance of the passage of time is of identical logical type to the movie in operation. Each event exists at a particular point in space-time along the world-line of the observer, a specific moment. Objectively, none of these moments has any special status; they all simply exist, laid out in space-time; but each moment becomes the Now as the moving frame of reference arrives at this point in space-time. The Now *is* the moving frame of reference; and each moment becomes the Now as the moving frame of reference coincides with this moment, as it passes along the world-line. Thus the status of any particular event is transitory. Momentarily, it becomes a special event as the moving Now coincides with its coordinates in space-time.

The problem of the Now was worrying because it meant that relativity is an incomplete description of the world. But it *is* a full and complete description of the *physical* world. The moving Now is a completely different type of phenomenon. It is a property of the universe, a third-logical-type phenomenon. It lies outside of the domain of the science of physics as currently formulated because the ontology is based exclusively on what can be explained in terms of physical reality. Since the moving frame of reference is a fundamental requirement to make sense of the physics, an extra ontologically fundamental category is required in order to complete the science. The train-window phenomenon is necessarily a property of the unitary system.

3 The C Word

As is directly evident to perception, the experiencing consciousness supervenes on the moving frame of reference. Here these are taken to be simply the subjective and objective attributes of the same fundamental property of the universe: the third-logical-type phenomenon of the moving Now.

If special relativity is taken at face value, there is no question of the static nature of the universe. As Deutsch emphasises:

> *Nothing* can move from one moment to another. To exist at all at a particular moment means to exist there for ever. (1997, p. 263; emphasis in original)

Weyl, however, states that consciousness does move in exactly this way:

> The objective world simply *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 continuously changes in time. (1949, p. 116; emphasis in original)

This inherently assumes a phenomenon contextual to the sequence of moments and events: the frame of reference of consciousness passes through space-time, crawling along the world-line of the body. Thus events are experienced in sequence as the Now progresses. Subjectively, in effect, the progression of proper time is enacted.

Such a concept is directly in contravention to the current worldview. Deutsch's statement begins by specifically excluding consciousness as the explanation:

> It is often said that … our consciousness is sweeping forwards through the moments. But our consciousness does not, and could not, do that. … *Nothing* can move … (ibid)

If this consciousness is just a property of the brain, a view widely held across scientific disciplines, a property of the physical, this is inevitably correct. It is this view, however, that is specifically repudiated by Chalmers' analysis. As he states:

> … experience must be taken as something over and above the physical properties of the world. (1996, p. 331).

Here it is essential to note that the word consciousness is routinely used quite indiscriminately for two entirely different classes of phenomenon, as both Block (1995) and Chalmers (ibid) explain. The first, which Chalmers calls psychological consciousness, encompasses cognitive abilities and functions. Block calls this access consciousness, meaning the accessing of information in the neural system to produce the: “... neuronal representations available for thought, decision, reporting and action” (2003, p. 8), i.e. the perceptual reality, that which is directly experienced. This is sapience, now well understood. The second, called phenomenal consciousness by both, refers exclusively to the experiencing awareness itself, the sentience. To date this has been a complete mystery. There is no trace of the experiencing consciousness in the brain, and apparently no possible explanation of the phenomenon. As Fodor states:

> Nobody has the slightest idea how anything material could be conscious. So much for our philosophy of consciousness. (1992)

As proposed by Chalmers, this phenomenon of conscious experiencing is a fundamental property of the universe:

> ... a fundamental feature of the world, alongside mass, charge, and space-time. (1995, p. 216)

As Weyl states: “... the consciousness in this function does not belong to the world.” (1934, p. 1). It is thus of the correct logical type to be an attribute of the moving frame of reference, passing from moment to moment in space-time. The word consciousness on its own is used here to refer to this phenomenal consciousness. Lockwood puts forward an ideal metaphor for the operation of this consciousness, quoting first Eddington and then Jeans:

> … events do not happen; they are just there and we come across them … In this case our consciousness is like that of a fly caught in a dusting-mop which is being drawn over the surface of the picture; the whole picture is there, but the fly can only experience the one instant of time with which it is in immediate contact (2005, p. 54)

Just as the frame of reference moves across the canvas, the frame of reference of the experiencing consciousness passes along the world-line of the observer. As Davies states: “... it appears that the flow of time is subjective, not objective.” (2002).

This is a purely subjective phenomenon, but no mystical miasma need surround this consciousness, and the presence of awareness. Fundamental, like mass, charge and space-time, this is simply the universe in dynamic operation. This is the resolution of the longstanding puzzle of why no trace of the experiencing consciousness can be found in the brain. It is not there. It is an attribute of the unitary system as a whole, of different logical type to anything in physical reality. Only such a phenomenon can produce these effects. The brain produces that which *gets* experienced, the perceptual reality, the product of access consciousness, but the conscious experiencing itself is an utterly different *type* of phenomenon.

Although the statements of Weyl and Deutsch are in direct contradiction they are both completely correct because they are addressing different levels of logical type. In the physical world, nothing can move from one moment to another any more than an element of the picture can move across the picture. Something contextual is required, and clearly consciousness is in this position.

The frame of reference of the experiencing consciousness cannot *not* move from moment to moment. To experience the reality of the wave function is to experience the enactment of the function it defines: the time-evolution of physical reality. This is 'what it is like' to use Nagel's (1974) famous term. The experience of the state vector by phenomenal consciousness is the experience of the change it defines. In consequence, this third-logical-type phenomenon constantly iterates the moments along the worldline of the observer. This accounts for the directedness of time.

As Tegmark states:

> … life is like a movie, and space-time is like the DVD … there's nothing about the DVD itself that is changing in any way, even though there's all this drama unfolding in the movie. (Kuhn, 2015)

As he explains, the movie of life does not run. Effectively, however, on the inside view, as the moving frame of reference passes along the worldline, it does.

4 The Origin

It is generally taken as obvious that *all* of consciousness is a property of the neural system. Without question the perceptual reality, the product of access consciousness, is of this nature. Equally, the location of the experiencing consciousness seems perfectly obvious, namely 'here', at the centre of the experiential domain. This, however, is just the coordinate of the *origin* of the *perspective* with respect to which the perceptual reality is formulated: this is the world hologram as described in Part 1. It tells us about the access consciousness: the world hologram it produces it is structurally identical to a virtual reality, being computed with reference to a specific spatial location. It tells us nothing about the phenomenal consciousness, except that this is the experience *of* the world hologram, with the perspective of the origin, *by* this phenomenon.

Because the world hologram is formulated with respect to the familiar location behind the eyes 'in here', this point of view is naturally identified as the location of consciousness. This, however, while precisely true of the origin of the world hologram, cannot tell us anything about the experiencing, the awareness itself. By analogy, the display of a computer obviously tells us nothing about who is experiencing it. Naturally, though, when it comes to the brain of a conscious individual, it seems totally obvious that it is 'me' that is doing the experiencing; but it is the 'me' in toto, the world hologram and the complete functional identity, that is *being* experienced. This is the experiencing *of* the brain, as an information process, *by* the consciousness.

The experience of this perspective naturally places the process of experiencing at this point, but there is nothing special actually there. The world hologram is the display of the navigation system of the human entity, and the origin is the centre point with respect to which it is formulated. As a result, when the world hologram is experienced, the point of view denoted as 'in here' is in this position – the '*I*' is '*here*'. Metaphorically, the '*I*' is '*here*' only in the same way as the light from the sun, reflected off a painting, is the light coming from the painting. The sun is not in the painting, and the phenomenal consciousness is not in the brain.

5 The Quantum Concept of Time

The moving frame of reference also explains the appearance of the enactment of the quantum-mechanical dynamics, and thus the appearance of change of the quantum state, exactly as described by Everett (1957). The collapse dynamics is the change of the quantum state of the observed environment, but as Barbour states: “The quantum universe just is. It is static.” (1999, p. 256). As Deutsch explains (1997, ch. 11) every possible physical state of the world exists 'already'. Each one is a static 'snapshot', the definition of the quantum state of a specific version of the physical world. Nothing moves and nothing changes. He refers to this as the quantum concept of time.

As he states, the essence is that: “Other times are just special cases of other universes” (1997, p. 278), where 'universes' are snapshots. All are laid out in a permanent matrix of coincident definitions. The whole system is a static layout of all possible versions of the physical world.[1] The static nature of the multiverse of snapshots is clearly evident once relativity and quantum theory are combined in the Wheeler-DeWitt equation. As stated by Barbour, this represents:

> … a time-independent Schrödinger equation for one fixed energy, the solution of which simply gives, once and for all, relative probabilities for each possible static relative configuration of the complete universe. Each such configuration is identified with a possible instant of experienced time. These instants are not embedded in any kind of external or internal time and, if experienced, exist in their own right. (1994, abstract)

In other words, all possible snapshots exist 'already'; and there is nothing that changes; and there is no possibility of movement from one snapshot, one instant, to another. Furthermore, there is no context in which these snapshots are arrayed in sequence, and no explanation of how one particular one might follow another in the experience of reality, as is constantly witnessed as the actual change of the world: the effective enactment of the collapse dynamics.

Since the quantum jump is the change of the quantum state, and this is static and permanent, it seems impossible to explain. Everett's formulation establishes the basis on which to resolve all these problems by showing how physical reality actually happens, *effectively*, for the individual on the inside view. As described in Part I, the individual on the inside view is the state of the memory, here the world hologram. As Everett shows, this is the protagonist of the collapse dynamics. On the making of each observation, a new correlation is established with the physical environment. In the quantum concept of time this means that the moving frame of reference becomes correlated with a different snapshot. Thus the making of each observation changes the effective physical frame of reference of the individual: the individual is now correlated with a different snapshot, a version of the world in which the change to the environment that was observed has determinately happened. Thus in effect, on the inside view, there is the transition from one snapshot to the next. This is the quantum jump, the change of the quantum-mechanical frame of reference. This is illustrated in Section 7.

1 “This understanding first emerged from early research on quantum gravity in the 1960s, in particular from the work of Bryce DeWitt, but to the best of my knowledge it was not stated in a general way until 1983, by Don Page and William Wooters. The snapshots which we call ‘other times in our universe’ are distinguished from ‘other universes’ only from our perspective, and only in that they are especially closely related to ours by the laws of physics. For that reason, we discovered them thousands of years before we discovered the rest of the multiverse.” (Deutsch, 1997, p. 278)

6 The Appearance of Collapse

Naturally there is no change to the physical world in all this, as there cannot possibly be in a static universe. The linear dynamics defines the static four-dimensional layout of possible events. The wave function cannot change. It is a mathematical formula. The collapse dynamics is the *effective* change of the formula. As Everett clearly states, there is only the *appearance* of collapse, 'Process 1':

> … the probabilistic assertions of Process 1 *appear* to be valid to the observer (1957, p. 459; emphasis in original).

In other words, this phenomenon occurs only on the inside view, in experience, as he explicitly states:

> It is found that *experiences* of the observer … are in full accord with predictions of the conventional "external observer" formulation of quantum mechanics, based on Process 1. (1957, p. 455; emphasis added)

Clearly, from direct and immediate evidence, something is changing. As Everett emphasises, the observed system does not change; it is the sum of the correlations with the environment that changes, thus defining observed events as having happened:

> *... it is not so much the system which is affected by an observation as the observer, who becomes correlated to the system*. (1973, p. 116; emphasis in original)

On the inside view, the addition of the observation to the world hologram alters the definition of the individual, and this alters the definition of the world superposition. In Everett's terms, the addition of the new correlation alters the relative state, the physical reality on the inside view.

Naturally, a moving frame of reference is required. Bitbol comments that in the analysis of Everett's concept:

> Something is still needed besides this description: pure cognitive capacity, the subject, or, in a very abstract sense: "mind". (1990, abstract)

Collapse occurs, on the inside view, as the world hologram is updated, the moving frame of reference passing from one snapshot to the next: the quantum jump. As described in Part 3 this process is of the logical type of an information process in a solid state system.

As with the sequence of moments in the passage of time, a phenomenon contextual to the snapshots is required to give even the appearance of collapse, and events happening, and this can only be a property of the unitary system. In the static universe, the experience of events taking place can only be the experience of the transition of this frame of reference from one snapshot to another.

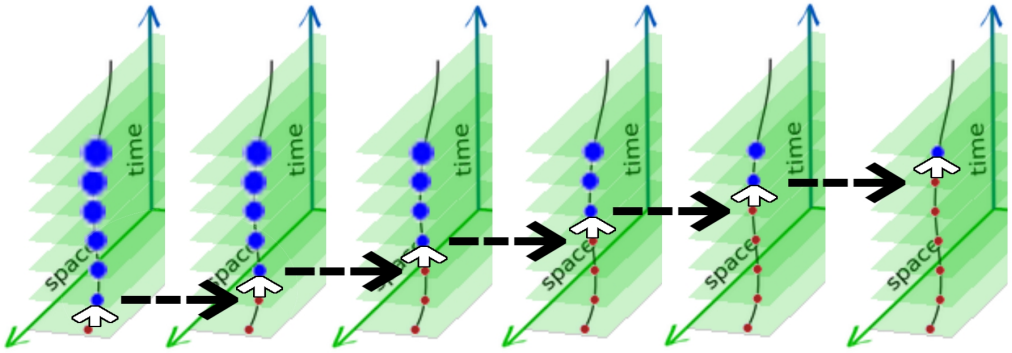
7 Times Two

There are two different kinds of time in the new physics: the time dimension of space-time, and the array of snapshots in the quantum concept of time. Their evolutions are effectively enacted, alternately, in the moving frame of reference. This is the cycle of operation of the linear and collapse dynamics as defined by the standard von Neumann - Dirac formulation of quantum mechanics:

> Process 1: If a measurement is made, then the system instantaneously and randomly jumps to a state where it either determinately has or determinately does not have the property being measured.
>
> Process 2: If no measurement is made, then the system evolves continuously according to the linear, deterministic dynamics
>
> (Barrett, 2008; adapted)

The quantum state of the system is defined by Everett's relative state: the record of observations is the record of observables defining the set of commuting operators which defines the determinacy of the observed system. As shown in Part 1, this is equivalent to the superposition of all quasi-classical worlds in which this individual exists. This is the quantum-mechanical frame of reference.

Each of the vertical worldlines in the illustration below exists in a specific snapshot, defined by a specific quantum-mechanical frame of reference. Process 2 is the change of the inertial frame of reference, *within* the context of that specific snapshot, as shown by the white arrows. The wave function spreads out as symbolised by the blue spheres. Process 1 is the change *of* this frame of reference, *in effect*, as each observation is made, as shown by the black arrows: the moving frame of reference passes to a different snapshot, a different definition of the quantum-mechanical frame of reference. As Lockwood states, this is a: "... dimension running, so to speak, *perpendicular to time and space*." (1989, p. 232; emphasis added).



A sequence of snapshots in the quantum concept of time.

8 Possibilism

This is the extra dimensionality Ellis is calling for as a requirement in the scientific worldview: a radical change to the current paradigm. This produces the evolving block universe:

> ... the unchanging block universe view of spacetime is best replaced by an evolving block universe which extends as time evolves, with the potential of the future continually becoming the certainty of the past; spacetime itself evolves, as do the entities within it. (2006, p. 1)
>
> This may be difficult to implement in physical theory, but it is actually the way things work; present theoretical physics understanding simply does not adequately represent it. (2008, p. 6)

The physical reality of the inside view defined by Everett, the relative state, grows in exactly this manner. Effectively, with progression from snapshot to snapshot, the four-dimensional space-time of relativity itself evolves: the potential of the future becomes the certainty of the past. This is illustrated by the progression of the growing line of red points representing the specific events observed.

Effectively, the enactment of the standard formulation produces the growing block universe of 'possibilism': the past is real and defined, and its boundary, the position of the Now, the present moment, is constantly moving into the future, which is merely possibilities. The past and the present are actual in the quantum-mechanical frame of reference, while the future is still just possibilities. As Ellis states: “... in terms of the metaphysics of time this view is that of possibilism” (2006, p. 22).

The difference between past and future is crystal clear, thus satisfying the final point of contention regarding the block universe raised by Lucas (ibid).

In principle, this framework is already present in the current understanding of the new physics because this *is* the quantum concept of time. As Deutsch (ibid) and Barbour (ibid) state, however, quantum time is a static array. Just as with the experience of the passage of time, this progression can only be a movement of the frame of reference, necessarily a third-logical-type phenomenon.

Given the moving frame of reference, all of the three classic metaphysics of time are defined by the physics simply taken at face value: presentism, eternalism and possibilism. All three potential logical arrangements are simply different attributes of the unitary system of relativity and quantum theory.

The white arrows are essentially presentism. As the gaze moves through space-time, only what is observed is real. The black arrows are possibilism. As this process operates, more and more of the effective physical environment is defined by correlations. The context – four-dimensional space-time, matter-and-energy snapshots – is eternalism, in both relativistic and quantum-mechanical contexts.

9 Identification

As described in Part 1 the missing piece of the puzzle in the meaning of quantum theory is the nature of the protagonist of the dynamics, the world hologram. To explain transtemporal identity there has to be an attribute of the protagonist that is of third logical type. The process of identification explains the genesis of the transtemporal conscious individual. The identification of the sentience with the world hologram, the product of sapience, produces the transtemporal protagonist.

As a system property of the universe, the frame of reference of the experiencing consciousness is not localised to a specific world. As stated by Bitbol, in and of itself: "... it is point-of-view-less, just as it is placeless and timeless." (1990, p. 8). It is quintessentially non-local, or perhaps better ubiquitous. Since it is present at all possible times and places, this would imply that it must necessarily embrace and include all possible frames of reference, thus all possible world holograms, all at once. Every possible phenomenal perspective is a specific point of view, and in principle it must have all possible points of view.[2]

On the inside view, however, there is only the experience of that specific world hologram, and therefore that specific frame of reference. As Bitbol explains, referring to the experiencing consciousness as Mind, this is the result of identification:

> Indeed, as soon as (abstract) Mind identifies itself with a point of view, it can but identify itself to a *particular* one. … the point of view Mind adopts, when adopted, is not one among others; it is *the* point of view, self-referred to as *my* point of view. (ibid; emphasis in original)

Therefore, although Mind experiences all possible versions of the inside view, *on* the inside view of each version there is only that one point of view: in that context *my* point of view. Just as reflected light takes on the pattern of information defined by the objects it illuminates, the ubiquitous phenomenon of Mind becomes the conscious experiencing of the perceptual reality of a specific individual, the world hologram.

This identification of phenomenal consciousness, universe consciousness, with the world hologram, the product of access consciousness, gives rise to the conscious individual, the perceiving subject that is the protagonist of the quantum-mechanical dynamics on the inside view. This is its genesis.

The process of identification also provides a further explanation of why all possible instances of a specific inside view must equate to one single instance in the universe. In this context there can be no such thing as an identical copy of a specific inside view: in the frame of reference of a ubiquitous phenomenon, identification with a specific inside view is identification with all the identical copies simultaneously. This provides further logic supporting the physical reality of the inside view being the world

2 This is not panpsychism, meaning a generalised thinking faculty, but simply raw awareness: panexperientialism, not pancognitivism.

superposition. Identified with this structure of information, present simultaneously in multiple versions of a quasi-classical world, the effective physical environment of this inside view is their superposed sum.[3] As shown in Part 1 this operates as defined in QBism, determinate solely where observed. This is the many-worlds reality.

10 Transtemporal Identity

As stated by Barrett:

> … in order to get probabilities out of the many-worlds theory, the first step is to provide an account of the transtemporal identity of observers. (2008)

An observer, meaning the physical mechanism as defined by Everett, cannot be transtemporal. As Deutsch (ibid) emphasises, *nothing* can pass from moment to moment. Given a moving frame of reference, however, the ongoing computation of the world hologram effectively produces a transtemporal protagonist.

Naturally, the sequence of states of the world hologram is of the same logical form as the structure of a movie. It also works in a manner logically identical to inter-frame compression in movies. The current frame is updated by applying the definition of the changes to the frame. The world hologram is updated by addition of the observation to the record. The experience of the sequence of states of the world hologram is the experience of the time-evolution of the perceptual reality and thus the movie of life.

In terms of structure the sequence of states is the transtemporal identity of the individual: the identity of the individual is the same from snapshot to snapshot except for the addition of each new observation. In terms of process the individual is transtemporal in action because this change is actually the time-evolution of the identity of this individual. In other words, the experience of life in reality is the experience of the time-evolution of the identity. Just as the moving frame of reference brings the dynamics of physics to life, so too the experience of the sequence of states of the world hologram brings the transtemporal individual to life.

On the inside view, the addition of the new observation is experienced as events happening, as the frame of reference is updated. The result is the four-dimensional space-time, matter-and-energy movie of life in action. Each frame is defined by the updated world hologram. In experience, physical reality effectively becomes transtemporal. The movie of life runs. As observations are made the current frame is updated. Each frame is defined by the record of observations, while the physical definition of each frame is the relative state, the quantum-mechanical frame of reference.

3 In this context the concept of world superposition applies to all 4 levels of a multiverse. in Tegmark's (2003) classification, including levels 1 and 2 where the identical inside views are at different locations in space-time.

11 The Perceiving Subject

A basic tenet of physics is that subjectivity must be ruled out. However, as Mermin describes, our worldview does not fit the facts *because* the conscious individual, the perceiving subject, has been excluded from the science:

> In *Nature and the Greeks*, Austrian physicist Erwin Schrödinger traced the removal of the subject from science back more than two millennia. Alongside the spectacular success of physical science, this exclusion of personal experience has given rise to some vexing and persistent puzzles and paradoxes.
>
> Two such unrelated long-standing problems are both resolved by recognizing that the perceiving subject has as important a role to play in understanding the nature of physical science as does the perceived object.
>
> The first problem is the notorious disagreement, confusion and murkiness that for almost a century has plagued the foundations of quantum mechanics, in spite of the theory's extraordinary usefulness and power. The second, less famous, problem has been with us at least as long: there seems to be nothing in physics that singles out 'the present moment'. Albert Einstein called this the problem of 'the Now'. Both problems are symptoms of the exclusion from physical science of the perceiving subject, and are solved by restoring what the ancient Greeks removed. (2014)

In the light of logical types as ontologically fundamental, it is clear why this is the case. The conscious individual, the perceiving subject, embodies the two logical types missing from the current ontology of physics. The paradoxes of quantum theory are resolved because the protagonist lives in a world superposition, a second-logical-type phenomenon, as described in Part 1. The paradoxes of relativity are resolved because the experiencing consciousness is the subjective attribute of the third-logical-type moving frame of reference, as implicit in Weyl's (ibid) dictum. All together this comprises the perceiving subject, the conscious individual.

There is a precisely world-hologram-shaped 'hole' in the physics. As Wilczek states:

> The relevant literature [on the meaning of quantum theory] is famously contentious and obscure. I believe it will remain so until someone constructs, within the formalism of quantum mechanics, an "observer," that is, a model entity whose states correspond to a recognizable caricature of conscious awareness, and demonstrates that the perceived interaction of this entity with the physical world, following the equations of quantum theory, accords with our experience. That is a formidable project, *extending well beyond what is conventionally considered physics*.

> Like most working physicists, I assume, perhaps naively, that this project can be accomplished, and that the equations will survive its completion unscathed. In any case, only after its completion might one legitimately claim that quantum theory is defined by the equations of quantum theory. (2006, p. 142; emphasis added)

This is the perceiving subject that has been rigorously excluded from the science, and the world hologram is literally the definition of these terms.

Firstly, as has been shown in Part 1, the states of this entity are the definition of conscious awareness at the physical level: the world hologram *is* the conscious awareness of the observer body-mind, meaning the perceptual reality instantiated in the memory. Secondly, there is no question that the interactions of this entity with the environment follow the equations of quantum theory because that is specifically what Everett demonstrates. It is “Judged by the state of the memory” (1957, p. 462), here the world hologram, that the dynamics of quantum mechanics effectively operate. In other words, the full operation of the standard formulation applies specifically and solely to the world of this entity. Thus the perceived interaction of this entity with the physical world precisely follows the equations of quantum theory; and it cannot but accord with one's experience because this *is* one's experience.

The world hologram is the "observer", meaning the protagonist of the dynamics. With this in place the paradoxes evaporate. The world that operates the mysterious collapse dynamics is the world superposition, the physical reality of this entity. This is what explains all the bizarre implications. As shown in Part 1, indeterminacy except where observed is natural in this type of world, inherent, axiomatic. Quantum Bayesianism is essentially correct, as are the many-minds theories: experience recorded defines the only determinacy of the physical reality, here the quantum-mechanical frame of reference. This is inside-view physics. The paradoxes of relativity are resolved by the moving frame of reference, a third-logical-type phenomenon of which consciousness is the subjective attribute. Naturally, the equations of physics remain unscathed.

The perceiving subject excluded from the physics is the world hologram experienced by consciousness, the product of sapience experienced by sentience. The world hologram defines the determinacy of the physical reality of the inside view: this is Everett's relative state. The sentience brings it to life.

12 Conclusion

Given the static and unchanging block universe of special relativity, the apparent time-evolution of the physical world can only occur at the level of appearances, as noted by Davies. Logically, to produce even the appearance of change, as in a movie or a virtual reality, progressive change of the frame of reference is an absolute

requirement. Given the static block universe, the frame of reference must move in space-time, from event to event, in order to produce the appearance of change. This resolves the great paradoxes of relativity. The Now, the present moment that cannot exist in the physics, is the view of the world in this moving frame of reference. The appearance of the passage of time is the immanent effect.

As is directly evident, the experiencing consciousness supervenes on the moving frame of reference. Thus a progression of moments is experienced as it crawls through space-time, as Weyl declares. Each event along the world-line becomes the Now, momentarily, as the moving frame of reference arrives at this point in space-time. This explains the *appearance* of the time-evolution of the world in the static physical universe; and effectively the linear dynamics is enacted. As Weyl states, the result is "... a fleeting image in space which continuously changes in time" (ibid). In effect time passes.

This process is punctuated by collapse. As observations are made, the frame of reference of the Now progresses from snapshot to snapshot. As Everett describes there is the *appearance* of collapse. Effectively, events happen in the static physical universe. Thus effectively, in experience, all the dynamics of physics are brought to life. This is the nature of transtemporal reality. It is in this domain and here alone that the dynamics of quantum mechanics actually happen.

The physical reality of the the protagonist, the world hologram, is the world superposition. This is Everett's relative state, here the quantum-mechanical frame of reference. The enactment of the linear dynamics, experienced as the transition through space-time, within the context of a specific quantum state, is like the fly being drawn across the canvas in Lockwood's analogy, passing along the sequence of moments in the worldline. The quantum jump to a different snapshot is like the duster moving to a different canvas, one where the scene defines a specific outcome of a new observation determinately made: the world defined by a slightly different quantum-mechanical frame of reference. This explains the effective enactment of the dynamics in the static eternalism of both relativity and quantum theory.

This perspective also enables a full operational definition of the transtemporal individual. The identity is the world hologram. This is the operational protagonist in the collapse dynamics. As Everett states, it is: "Judged by the state of the memory" that the dynamics of quantum mechanics effectively operate. This is the self-aware substructure of the system to use Tegmark's (1998) phrase quoted in Part 1. It is quintessentially self-aware because it actually is both the identity and the perceptual reality, the world hologram: it is that of which awareness is aware. This is the "observer" Wilczek defines as a requirement for the completion of the understanding of the quantum theory.

The perceiving subject is the product of access consciousness, sapience, experienced by phenomenal consciousness, sentience. The key point is that these are phenomena operating at different levels of logical type. The conscious transtemporal individual, the perceiving subject, is the resulting phenomenon, an emergent property

of the unitary system. The perceiving subject has been studiously omitted from the science of physics as Mermin describes, but it is significant in a manner that has been incomprehensible.

The solution lies outside the boundary of the questions being asked, but this is classic scientific revolution. The new paradigm does not fit into the current worldview, and this is the reason it seems wrong, but as usual the new paradigm subsumes the old. The objective physical world is exactly as defined in the current paradigm, but the physical reality encountered is a world superposition, a second-logical-type phenomenon. As has been shown, this does not involve any change to the physics. This is a purely conceptual revolution. The ontological dualism reconciles the paradoxical measurement problem of quantum theory. The linear and collapse dynamics operate at different levels of logical type. The third logical type resolves the paradoxes of special relativity.

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