Subjective Time in Neuropsychology *vis-a-vis* the Objective Time of Physics

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ABSTRACT

The notions of objective time and subjective time are reviewed and the relativity that obtains in case of each in different specific circumstances is discussed. Various aspects of subjective time perception have been discussed such as retrospective and prospective paradigms, frequency of neural oscillations, neural recruitment, information processing rate, centralized versus distributed timing mechanisms, State Dependent Networks (SDN), emotional states, attention, memory, psychological disorders and neuropharmacology of time perception. For objective time, its relativity in special and general theories, multidimensionality, existence of closed time-like curves, arrows of time, cyclicity of cosmic time, the time energy-time and space-time uncertainty relations have been discussed. Among the arrows of time the psychological arrow falls in the subjective category while the other arrows are on the objective side. As a possible resolution of the conflict of supremacy of one arrow over the others or of one arrow generating the others, it is argued that the psychological arrow may be the fundamental one which generates the rest of the arrows. The cross-disciplinary relevance of the article is emphasized and some important philosophical positions on the notion of time and its division into past, present and future are also discussed.

Key Words: Subjective Duration, Objective Time, Relativity of Time Perception, Neural Recruitment, Information Processing Rate, Arrows of Time

DOI Number: 10.14704/nq.2018.16.11.1850 **NeuroQuantology 2018; 16(11):1-11**

Introduction

One of the most mysterious ingredients of our experience is that of time. There is nothing physical corresponding to its existence though it is taken as a marker for all physical processes. Kant included time as an *a priori* precondition of experience along with space (Kant, 1998). In classical physics time is absolute flowing equably for all observers (Newton, 1686): "…Absolute, true and mathematical time, of itself, and from its own nature flows equably without regard to anything external, and by another name is called duration: relative, apparent and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time."

In the course of the development of the special theory of relativity Einstein in a flash of insight came to the conclusion relative nature of time (Shankland, 1963): "… until it came to me that time was suspect*!*" Thus, time became dependent on the motional state of the observer and is taken as the fourth dimension of the space-time continuum. Minkowski (Minkowski, 1952) joined time and space into a four-dimensional continuum: "Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality**…**Three-

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 24 July 2018; **Accepted:** 6 August 2018

dimensional geometry becomes a chapter in four-dimensional physics. Now you know why I said at the outset that space and time are to fade away into shadows, and only a world in itself will subsist".

Einstein (Einstein, 1962) reinforces "It appears... more natural to think of physical reality as a four-dimensional existence, instead of, as hitherto, the evolution of a three-dimensional existence".

Rovelli (Rovelli 2011) therefore opines that time as a cosmic flow, as all thinkers up to Einstein believed to be existing, dos not really exist in that sense but the instants of time as the markers of change: ".... Change is not described as evolution of physical variables as a function of a preferred independent observable time variable. …To put it pictorially: with general relativity we have understood that the Newtonian "big clock" ticking away, the "true universal time", is not there."

In quantum physics time enters the Schrodinger equation as a parameter and as the conjugate to the Hamiltonian or energy function of the system (Aharonov and Bohm, 1961; Bauer, 2017). This objective time of physics, which in cosmological sense is taken to have begun with the Big Bang and is assumed to continue indefinitely in an open universe while in a closed universe scenario, it is supposed to come to an end at the Big crunch (Hawking, 1988). An interval of such objective time is assumed to be made up of a definite number of assumed macroscopic time units *i.e.* seconds, and is independent of observers and is recorded by instruments such as clocks.

The views expressed by scientists since the time of Newton on the concept of time shows that there is still a lot more left to be done in order to understand time by devoting ourselves to find solutions within the paradigm of modern physics to the most important questions. The possibility of multidimensionality of time, existence of closed time-like curves (CTC) (Gödel 1949), emergence of time from change (Manousakis 20016), role of time in quantum theory (Aharonov and Bohm, 1961), cyclicity of cosmic time (Hopfstadter and Turok 2002), the interpretation of time-energy uncertainty relation (Bohm 1986), space-time uncertainty relations and the unification of the arrows of time (Zeh 2010) are some of the fundamental issues that beset the current understanding of time in Physics.

On the other hand, the subjective experience of time and how an individual interprets the duration of an event (Walsh, 2003) has been studied by neurobiologists and psychologists to arrive at many interesting conclusions. Depending on the occasion, people may feel that time passes quickly or slowly compared to clock time or objective time (Block and Grüber, 2014). In addition to being related to several cognitive and behavioral actions, it is also dependent on the way in which the central nervous system processes environmental information. Distortions of time perception are also associated with specific psychiatric and neurologic diseases and disorders (Lucas *et al.,* 2013) leading to some understanding of the neural functionality of time perception in relation to some diseases. There is a consensus that individuals who suffer from impairments of time perception lack a specific pathway that carries key information about the passage of time from the external environment to the brain (Allman and Meck. 2012).

In general, temporal perception includes all sensory channels. However, it is not clear as to the extent to which these representations are mediated by neural structures (Coull, 2011). Moreover, there are diverse brain regions associated with the sense of time (frontal cortex, basal ganglia, parietal cortex, cerebellum, and Hippocampus) are responsible for receiving, associating and interpreting information in fractions of milliseconds, seconds and minutes. These neural processes are completed only through the participation of memory, attention, and other emotional states (Buhusi and Meck, 2005). For this reason, on many occasions, time can be hyper or hypo estimated. For instance, when we are looking forward to an important event, such as the day we are going on vacation, time seems to pass more slowly than when the vacation is coming to an end and we are close to return to work. Different time perceptions can be attributed to the differences in the ways we perceive daily activities in addition to being influenced by other psychiatric and neurological factors. Studies involving individuals who suffer from attention deficit hyperactivity disorder (ADHD), depression, schizophrenia and Parkinson's disease (PD) have revealed that individuals with such conditions often have an impaired time perception.

Emotional states such as anger, fear and sadness etc. have also been known to affect time

*e*ISSN 1303-5150

perception as also neurological and physiological disorders like schizophrenia, ADHD (Droit-Volet, 2013, Teixeira, *et al*., 2013, Fontes, 2016).

In this study we present a contrast of subjective and objective time, dilating upon each in considerable detail. There is frame dependence of objective time in the special and general theories of relativity while subjective time perception depends on neural information processing rate, frequency of neural oscillations and neural recruitment. Many unsolved problems face both of them and a unification is nowhere in sight.

Relativity of Subjective time perception

Experience tells us that perception of change is essential for perception of time (Manousakis, 2006) since we find that when no change is perceived in a particular mental state- as in deep sleep, swoon, coma, deep meditation etc. - no temporal flow is perceived by the individual concerned (van Wassenhove *et al*., 2011). This is the subjective time. An observer's judgment of such a duration of subjective time depends on various factors such as attention, emotion, memory and other pathological conditions, specific diseases or impairments. For example, an objective time interval Δt may appear subjectively to be comparatively longer or shorter to an observer depending on these factors. If subjective time passes slowly compared to objective time, we have $\Delta s < \Delta t$ and when it moves faster we have $\Delta s > \Delta t$, where Δs is the corresponding subjective duration.

Psychologists have been dealing with measurement of subjective duration by the study of interval length estimation and subjective passage of time judgments (Sucala et al., 2010). Freeman Dyson (Dyson, 1990) proposed to relate subjective time with the information processing rate in terms of the metabolic rate.

In general the subjective estimate Δs and its corresponding objective interval Δt are expected to be linearly related:

$$\Delta s \; \alpha \; \Delta t \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

However, depending on the level of attention, interest and absorption in an activity, Δs can be larger or smaller than Δt due to a complicated functional dependence (Pradhan and Tripathy, 2018) on the information processing rate and the neural recruitment.

Subjective duration and neural oscillations

While change is essential to the perception of passage of time, measurement of time is always done with the help of periodic changes. For example the lunar and the solar calendars are based respectively on the apparent periodic movements of the moon and the sun while modern day clocks use periodic oscillations of quartz crystals for the purpose. The currently accepted definition of the objective time unit (1 second) is taken to be 9192631770 oscillations of the radiation produced by the transition between the two hyperfine levels of the ground state of Cs - 133 atom.

In biological systems, different chrono-biological rhythms serve as internal time reckoners for an organism (Hedge, 2013). This could range from the average mitosis period for a unicellular organism like amoeba, to the respiration rate or cardiac cycle for a higher animal. It can even be one of the longer duration cycles like those associated with food, sleep and reproduction etc.

All the above periodicities however, have nothing to do with time perception by an individual; rather they are more associated with the health of the individual. Perception of time can be assumed to be more directly related to neural frequencies rather than to any other biological rhythms (Ivry and Spencer, 2004; Mauk and Buonomano, 2004). Neuronal oscillations corresponding to single neurons at micro scale, local ensembles at the meso-scale and global non-local oscillations across different brain regions at the macro scale have been observed and models have been proposed for them viz. Hudgekin-Huxley (Hudgekin & Huxley, 1952) model for single neuron, Willson-Cowan (Wilson & Cowan, 1973) model for ensembles and Kuramoto model (Kuramoto, 1984) for macro scale binding oscillations respectively and their many variations. The frequency bands primarily observed and classified by Berger (Berger, 1940) are δ-band (1-4 Hz), θ-band (4-8Hz), α-band (8-12 Hz), β-band (12-30 Hz), γ-band (30-70), Γ-band (70-150 Hz) corresponding to different levels and functions of awareness e.g. δ-band for sleep, θ-band for dream and memory, α-band for auditory perception, γ-band for visual perception, Γ-band for cognitive processing etc (Buzsáki and Draguhn, 2004).

Role of Attention in time perception:

To judge a duration, we need to pay attention to that duration when we are directly required to respond to a duration estimate experiment. Prospective and retrospective duration judgments have yielded different variations of subjective duration with objective duration (Gruber et al., 2000; Coull et al. 2004). Psychological disorders like ADHD and schizophrenia lead to attention deficits and thus affect time perception (Droit-Volet, 2013).

The neural systems responsible for spatial and temporal attention have been studied using PET (Positron Emission Tomography) and fMRI (functional magnetic resonance imaging) techniques (Coull and Nobre 2008), which show activity in different brain regions corresponding to the neural correlates of attention.

This means that attention is a key factor in temporal judgment and has to be taken into account in finding the expression for subjective duration in terms objective time. Since, definite neural correlates have been identified in attention tasks (Coull and Nobre 2008), the total number of neurons activated during a period of attention must be different from that in the period of no attention or comparatively less attention.

Different brain regions involved in directing attention towards temporal intervals have been imaged with PET and FMRI by assessing the relative efficiency of judging time intervals with stimuli that occurred at predictable and unpredictable cued intervals (Coull and Nobre 2008).

Centralized verses distributed timing mechanisms

Because of the involvement of neuronal assemblies in different brain areas in time perception (Muller and Nobre, 2014), it has been proposed that timing mechanism may be different for different assemblies such as the hippocampal, cortical, basal ganglial and so on (Coull *et al*., 2011). Depending on the modality the assemblies may be having different frequencies of neuronal oscillations as well as different recruitments. However, when a duration judgment is made it is neither hippocampal nor striatal nor cortical but is a unique subjective estimate, which may be taken to be the mean of all these distributed estimates.

The perception of time is the resultant of the stimuli associated with cognitive processes and environmental changes. It requires a complex neural mechanism and depends on emotional state, level of attention, memory, diseases and disorders of the brain etc. Different areas of brain such as the frontal cortex, basal ganglia, parietal cortex, cerebellum and hippocampus (Fontes, 2016) have been found to be involved in the temporal perception by receiving, processing, associating and interpreting of the information processed in the interval from milliseconds to minutes (Gibbon and Russel, 1981; Buhusi and Meck, 2005, Ivry and Spencer, 2004). Time is perceived by decoding the time varying activity of large number of neurons distributed over different neural assemblies (Matell *et al.,* 2003).

Encoding time in Neural Network States:

A number of models of timing have been suggested in the literature (Buhushi and Meck, 2005). The State Dependent Networks (SDN) models propose that neural circuits are inherently capable of temporal processing as a result of the natural complexity of cortical networks coupled with the presence of time-dependent neuronal properties. It is based on well-characterized cellular and network properties and is able to discriminate simple temporal intervals in the millisecond range as well as complex spatial and temporal patterns. This model suggests that within the millisecond range time perception does not rely on clock-like mechanisms or on a linear metric of time.

Time perception mechanisms in the central nervous system:

The five senses have specific ways to receive environmental information and lead to central nervous system. The perception of time is the sum of stimuli associated with cognitive processes and environmental changes. Thus, the perception of time requires a complex neural mechanism and may be changed by emotional state, level of attention, memory and diseases. Despite this knowledge, the neural mechanisms of time perception are not yet fully understood. The objective is to relate the mechanisms involved with the neurofunctional aspects, theories, executive functions and pathologies that contribute to the understanding of temporal perception.

Time perception and memory

Everyone is continuously involved in temporal activities, such as controlling the timing of a movement, expressing general knowledge, representing events and remembering past episodes (Hintzman, 2005). This information is filed into a system of storage (memory) and can be recovered when requested (Squire, 2004). In this context, human memory plays an important role in terms of our perceptions (Eichenbaum and Chen, 2001). Specifically, four systems of memory are involved to a greater or lesser extent in different experiences (Hintzman, 2005). Namely, the *semantic memory* (responsible for processing information, like concepts, linguistic expressions and facts); the *procedural memory* (involved in the performance of relatively automatic movements and of learned movements); the *working memory* (responsible for processing information about current or recent past events) and the *episodic memory* (responsible for processing past personal information (Baddeley, 1997).

Moreover, time perception is involved with diverse cognitive processes (Gold and Squire, 2006). Existing studies have noted that the less the attention paid to a task, the greater the reduction in subjective time perception (Staddon, 2005). Studies on patients with amnesia demonstrated that individuals who suffer from this condition are less able to precisely assess temporal judgments of short duration (less than 10 seconds) and more likely to underestimate longer temporal durations (more than 10 or 20 seconds); however, these studies linked the deficits only to a dysfunction of the long-term memory (Mimura and Kinsbourne, 2000). Based on this notion, Pouthas and Perbal (Pouthas and Perbal 2004) conducted further research using tasks which involved the reproduction of time and production to assess the capacities of distribution that a patient with amnesia shows in terms of selective deficit on episodic memory. Some studies on time perception dysfunctions (PD) in patients with PD have explained such impairment in terms of an internal timing mechanism (Harrington and Haaland, 1999). In this way, memory is associated with temporal perception as exemplified by the difficulty of the patient with PD in the interpretation of time.

A specific experiment of Karmakar and Buonomano

An SDN (State Dependent Network model) composed of 400 excitatory and 100 inhibitory recurrently connected integrate-and–fire units was stimulated using the software NEURON. The synapses in the network exhibit short term synaptic plasticity. Which particular neurons are activated during an interval is determined by the network's random connectivity, assigned synaptic strengths and short-term plasticity enabling us to encode time in a spatial code (in the functioning of the neurons in the network). It turns out that there is no explicit or linear measure of time like the ticks of a clock. Instead, time is implicitly encoded in the state of the network defined not only by which neurons are spiking but also by the properties that influence cell firing such as the membrane potential of each neuron and synaptic strengths at each point in time. The results show that timing is not centralized and can occur locally at both early and late stages of cortical processing (respectively for small and large durations).

Retrospective and Prospective estimates of time

Retrospective and Prospective subjective duration estimate experiments reveal that the perceived time duration is in general different from the external objective interval depending on factors such as attention, memory and psychopathological conditions etc. Prospective duration estimate is done by asking the subjects to estimate the duration prior to the presentation of the interval, while in retrospective estimate subjects are asked to judge the duration after the completion of the presentation of the interval.

A person may make a duration judgment under either of two instructional conditions. The prospective paradigm is defined as a situation in which a person is aware, during a time period, that he or she needs to estimate its duration. Because of this awareness, Block (Block, 1990) referred to a duration judgment using this paradigm as one assessing experienced duration. In the retrospective paradigm, a person becomes aware of the need to judge a duration only after it has ended. In this paradigm, a duration judgment must rely mainly on information retrieved from memory. For this reason, Block referred to this paradigm as one assessing remembered duration (Zakay and Block, 2004).

Prospective duration timing depends on attention-demanding processes that occur concurrently with the processing of nontemporal information (Pouthas and Perbal 2004 – this issue). Thus, prospective timing is a dual-task condition: a person must divide attention between temporal and nontemporal information processing, and attending to time requires access

eISSN 1303-5150

to some of the same resources that nontemporal tasks use. For this reason, models of experienced duration usually emphasize attention (Block and Zakay, 1996; Zakay and Block, 1996).

Models of retrospective timing therefore usually emphasize memory (e.g., Block 1990, Ornstein 1969). Ornstein's storage size hypothesis is one of the more durable models of remembered duration.

Neuropharmacology of time perception

Current pharmacological research suggests that the different stages of temporal processing may involve separate brain regions and be modified by different neurotransmitter systems. The internal clock used for timing in the seconds to minutes range appears to be linked with dopamine (DA) function in the basal ganglia, while temporal memory and attentional mechanisms appear to be linked to acetylcholine (ACh) function in the frontal cortex. These two systems are found to be connected by frontal-striatal loops which allow for completion of the time perception process in a sequential manner (Meck, 1996).

Now we turn to the objective time of Physics and likewise discuss the issues relating to it.

Frame dependence of objective time in Relativity

Einstein, in a flash of intuition came to the realization of the relativity of time and successfully derived (Einstein, 1905) the Lorentz Transformation equations for their speed-dependence.

$$x' = \gamma\,(x - vt);\; t' = \gamma\,(t - \frac{vx}{c^2})\,;\, y' = y;\, z' = z;\; \gamma = [(1-(v^2/c^2)\,]^{-1/2} \qquad (2)$$

Similarly, the curvature of space-time around massive objects leads to another frame relativity of time which leads to the gravitational time dilation effect.

Multidimensionality of time

In Special theory of relativity describes space-time is a manifold whose metric tensor has a negative eigen value corresponding to the existence of a "time-like" direction. The special relativistic metric tensor given by the signature $(+\;-\;-\;-)$ is defined by the geodesic element:

$$ds^2 = (ds_{1,3})^2 = dt^2 - dx^2 - dy^2 - dz^2 = g_{\mu\nu}\, dx^{\mu}\, dx^{\nu} \qquad (3)$$

$g_{\mu\nu}$ is the metric tensor and we have used the Einstein summation convention (repeated indices are summed over) with the identifications:

$$dx^0 = dt, dx^1 = dx, dx^2 = dy, dx^3 = dz \qquad (4)$$

A metric with multiple negative signatures would likewise imply *several* time-like directions, i.e. multiple time dimensions but the relationship of these extra time dimensions to the one time that we know is not clear (Velev, 2012). If the special theory of relativity can be generalized for the case of *k*-dimensional time $(t^1, t^2, \ldots, t^k)$ and *n*-dimensional space $(x^{k+1}, x^{k+2}, \ldots, x^{k+n})$, then the $(k + n)$-dimensional invariant interval can be written as:

$$(ds_{k,n})^2 = (cdt^1)^2 + \ldots + (cdt^k)^2 - (dx^{k+1})^2 - \ldots - (dx^{k+n})^2 \qquad (5)$$

Implications of such a space-time can well be imagined when observers would be living along different orthogonal time axes or be having time-components along different axes with the weirdest possible fallouts.

Closed Time-like Curves (CTCs)

A closed timelike curve (CTC) is a "closed" worldline of a material particle in spacetime (*i.e.* in a Lorentzian manifold) that returns to its starting point. This possibility was explored by Kurt Gödel(Gödel, 1949) who discovered a solution to the equations of general relativity (GR) allowing CTCs, known as the Gödel metric; and since then other GR solutions containing CTCs have been found, such as the Tipler cylinder (Tipler, 1974) and traversable wormholes. If CTCs exist, their existence would seem to imply, at least the theoretically, the possibility of traveling backwards in time, raising the problem of the grandfather paradox. However, the Novikov self-consistency principle (Novikov, 1992) seems to show that such paradoxes could be avoided. The chronology protection conjecture is formulated to rule out these CTCs of GR in a possible quantum theory of gravity (Bonnor and Steadman, 2005).

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Emergence of time from change

Manousakis (Manousakis 2006) has proposed that Periodic change or fluctuation is a fundamental element of consciousness. Consciousness perceives time only through the direct perception of change through an event; the value of the time interval between two successive events in consciousness is only found by counting how many revolutions of a given *periodic event* took place during these two events. Therefore the notion of time is related to the sequential (ordered) events which allow counting, and the interval of time and change (in particular periodic change) are complementary elements and they are not independent of each other. There is physiological evidence suggesting the *direct* perception of frequency. For example, we perceive the frequency of sound directly as notes or pitch, without having to perceive time and understand intellectually (after processing) that it is periodic.

The quantum state which describes a periodic change is such that when the time displacement operator acts on it, it behaves as its eigenstate. He derives time as resulting from the operations of consciousness on the state of potential consciousness and when the operated state of potential consciousness is measured against its own state before the operation, a definite frequency is realized. There is physiological evidence suggesting the *direct* perception of frequency. There is significant neuro-physiological evidence that the perception of time takes place via coherent neuronal oscillations which bind successive events into perceptual units. Nature responds to frequency very directly, and some examples are resonance, single photon absorption and in general absorption at definite frequency. Thus the time interval can be seen to emerge from summation of such definite units of time bits $(\tau = 1/\nu)$.

Cyclicity of Cosmic Time

A cyclic model (or oscillating model) is any of several cosmological models in which the universe follows infinite, or indefinite, self-sustaining cycles. For example, the oscillating universe theory briefly considered by Albert Einstein in 1930 theorized a universe following an eternal series of oscillations, each beginning with a big bang and ending with a big crunch; in the interim, the universe would expand for a period of time before the gravitational attraction of matter causes it to collapse back in and undergo a bounce (Steinhardt and Turok 2002).

Time-energy uncertainty relation

The Heisenberg uncertainty relation for energy and time is:

$$\Delta t.\Delta E \geq (\hbar/2) \tag{6}$$

But unlike other uncertainty relations (e.g. for position and momentum and for angle and angular momentum) it does not have a direct interpretation since time in quantum mechanics is not an operator but as a parameter for evolution of states as per the Schrodinger equation. (Hilgevoord 1998, Aharonov and Bohm 1961).

Space-time uncertainty relations

In theories of quantum gravity such as string theory (Seiberg and Witten, 1999), the space and time coordinates lose their simultaneous measurability as the space-time structure becomes foamy in the near Planckian regime with length dimensions $\sim l_P = \frac{G\hbar}{c^3} \sim 10^{-32}\,cm$. Such space-time uncertainty relations lead to fuzzy space-time in the spin network models for space. It leads to the non-commutativity of space and time coordinates. Non-commutativity implies simultaneous non-measurability of the space and time coordinates. Thus in the absence of exact values for locations and instants the spacetime becomes inherently fuzzy (Yoneya 2000).

Arrows of time

The thermodynamic arrow corresponds to the direction of increasing disorder and hence of entropy. Thus it is also called the entropic arrow of time. It follows from the second law of thermodynamics. Time proceeds in the direction of the increase of entropy (Eddington, 1928). The Cosmological arrow of time is the direction in which the universe is expanding at present. The quantum mechanical arrow of time is the direction in which wave function collapse or state vector reduction occurs leading to definite state from among many possibilities. The psychological arrow of time is the direction from past to future that we assign to perceptual time because we remember the past and not the future. Whether all these arrows are distinct or they have a common origin is not yet clear though mappings of one to the other have been proposed in the literature (Zeh, 2010).

The Psychological arrow

Apropos the psychological arrow of time, it has been generally assumed to be a future directed one because of the very make up of our perceptual apparatus. When the perceiving individual psyche associates itself with the perceived succession of events, it finds them moving backwards in the past direction. Thus the relativity of perception of movement lets one conclude that time has a future directed arrow. On the other hand when the psyche stations itself in the present moment, the only perception is that of a rushing of events in the past direction in the memory space and accordingly the time attached to these past moving events also seems to proceed in the past direction.

To clarify this relativity with an analogy a boat moving down wards with the flow of a river sees the banks moving upwards while an observer standing on the banks sees the river flowing downwards. Here the river represents time, the boat an event and the banks represent the present moment.

Which arrow is primary?

The question of primacy and supremacy of one arrow over the rest has its origin in the mind-matter duality. The materialists argued that the perception of a psychological arrow is dependent on the neural processes in the brain which follow the thermodynamic arrow and thus the latter is the progenitor the former.

On the other hand, the idealists argue that the very notion of the existence of time itself is dependent on a perceiving psyche and so also are the notions of entropy, its increase and that of the directedness of movement. It is precisely the past directed movement of the events, tethered to the respective instants of their happening in memory that gives the sense of the existence of a future-directed time (as seen from the standpoint of those past moving events in memory).

Thus, the psychological arrow takes precedence over all the other arrows since they presuppose the existence of a time, which itself is dependent on event perception by the psyche. It is the association of the psyche with the present moment that gives the perception of a past directed movement of events in the river of time and the same psyche associated with those past moving events that gives the sense of forward movement of the present moment.

Some philosophical positions on time

Regarding the views of philosophers across millennia on time, Markosian (Markosian, 2008) summarises: "...Aristotle and others (including, especially, Leibniz) have argued that Time does not exist independently of the events that occur in time. ... The opposing view… has been defended by Plato, Newton, and others. On this view, time is like an empty container into which things and events may be placed; but it is a container that exists independently of what (if anything) is placed in it*."*

Dowden (Dowden, 2005) contrasts this with the views of Rene Descartes: "... René Descartes had a very different answer to "What is Time?" He argued that a material body has the property of spatial extension but no inherent capacity for temporal endurance, and that God by his continual action sustains (or re-creates) the body at each successive instant. Time is a kind of sustenance or re-creation." Dowden finally summarizes:"… Time is what clocks measure. We use our concept of time to place events in sequence one after the other, to compare how long an event lasts, and to tell when an event occurs. Those are three key features of time. Yet despite 2,500 years of investigating time, many issues about it are unresolved.

On the philosophical issues regarding the reality of the present compared to the past that has gone and the future that is yet to come, we quote Peterson and Silberstein (Peterson and Silberstein, 2009):

"This problem stems from two competing notions of time. The first, originally suggested by Heraclitus, ...is the view that only the present is real; both the past and the future are unreal… However, with the advent of relativity, a different stance, whose primary ancient proponent was Parmenides of Elea ... was translated into the language of relativity of Hermann Minkowski in 1908 to suggest that time and space should be united in a single, four-dimensional manifold. Thus arose the notion of a 4D "block universe" ... in which the past, present, and future are all equally real."

McTaggart (McTaggart, 1908) analysed different temporal series of events and claims that time in past, present and future cannot be divided as it has been experientially done, since it is fundamentally impossible to define them without assuming their prior definition: **"...**It would, I suppose, be universally admitted that time involves change…" But, after considering distsinct temporal series of events (A, B and C series), he concludes "...We cannot explain what is meant by past, present and future." ... "Our ground for rejecting time, it may be said, is that time cannot be explained without assuming time"

Similarly, Butterfield (Butterfield, 2002), after a painstaking analysis of time, prefers to denounce its existence altogether: "...Physicists are able to compactly summarize the workings of the universe in terms of physical laws that play out in time. But this convenient fact should not trick us into thinking that time is a fundamental part of the world's furniture ... But it, too, **...** is a convenient fiction that no more exists fundamentally in the natural world than money does."

Discussion

Various aspects of objective and subjective time perception have been discussed in the article which reveals a clear understanding of the objective time of Physics and the subjective experience of time in the domains of psychology and neurobiology. The article brings into focus the relativity of objective time in terms of subjective perception. Much of the relativity of objective time is frame relativity-- one of the four types of objective relativity possible, but the relativity of subjective time perception can be any of the four categories (sensory, brain state, perceptual, conceptual) of subjective relativity or their possible mixtures (Pradhan, 2014). Subjective perception varies infinitely in infinite events as per the subject-object perception method and mechanism in terms physics, psychology and neurobiology. This makes it very difficult to have a theory for subjective time that would explain its various characteristics in one compass. The equation for subjective time in terms of objective time proposed recently by us (Pradhan and Tripathy, 2018) is an attempt to fill this gap but still more research is required in the relevant cross-disciplinary areas for bringing universal experimental validity.

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