The Perception of Time by Humans according to John Philoponus and its relation with the Theory of Special and General Relativity

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Abstract

The significance of the observer in the perception of time has been pointed out by the Byzantine scholar, philosopher and physicist John Philoponus (6th century AD). According to Philoponus, the perception of time by humans depends on the measurement of the motions of the celestial bodies. Correspondingly, in the special theory of relativity humans perceive time in relation with the frames of reference, while in general relativity theory time as an integral part of spacetime is curved with the curvature being a function of the nearby mass.

Keywords: Philoponus. Time. Relativity Theory. Observer

1. Biography of John Philoponus

John Philoponus, also known as John the Grammarian or John of Alexandria, was a Christian Monophysite Church author, philosopher, grammarian, mathematician, physicist, astronomer, in short one of the most distinguished scientists of the sixth century in the Byzantine (Eastern Roman) Empire. A great philosophical and spiritual mind, he was called “Philoponus” (a composite Greek word meaning literally the lover of toil) most probably because of his incessant occupation with the tiring study of books and philosophy. According to another version, he was called “philoponus” because he belonged to the Monophysitic sect that bore the same name (Theodossiou & Danezis, 2010). He is also known as John of Alexandria because he studied in the School of Alexandria under the Neoplatonic philosopher Ammonius.

As a philosopher, Philoponus is considered one of the main proponents of the Christian dogmas about the Universe and an opponent of the respective Aristotelian beliefs. Indeed, according to Manolis Kartsonakis: *“He raised objections on vital points of the Aristotelian principles about nature, where his Christian educational background, combined with the Neoplatonic orientation of the Alexandrine School he followed, was at odds with the Aristotelian model”* (Kartsonakis, 2005).

The life, the intellectual evolution and the work of John Philoponus are closely related with the city of Alexandria and its Neoplatonic School, since for many years he was a pupil of the Neoplatonic philosopher Ammonius, who in turn was the student of Proclus at the school of Athens. Although the Aristotelian and Neoplatonic tradition were sources of his intellectual quests, John, as an excellent specialist on the works by Plato and Aristotle, was the pioneering philosopher who eventually differentiated from that tradition and paved a part of the road which led to the novel approach of natural sciences. He is considered one of the representatives of Christian Aristotelianism, while his work exerted a considerable influence on the Mediaeval natural sciences, particularly on intellectuals and scholars such as Jean Buridan (14th century), Nicolas d’Oresme (1323-1382), Nicolaus Cusanus (1401-1464), Johannes Kepler (1571-1630), Galileo Galilei (1564-1642) and others (Theodossiou, 2007).

John Philoponus also tackled a large variety of topics, in the fields of philology, logic, mathematics, physics, psychology, cosmology, astronomy and theology. Although his fame was established mainly through his commentaries on Aristotelian works, he had in mind the eventual liberation of natural philosophy from the restricting cloak of Aristotelianism, which he attempted to harmonize with the Christian teachings.

2. Time and the Universe (cosmos)

The study of time by Philoponus starts from the assumption of the unbreakable connection of time with the existence of the world. He writes characteristically that time *"was generated together with the heavens"* (Philoponus *De aeternitate mundi*, 115, 17), stressing its parallel existence with the Universe. Consequently, the physical processes that take place in the natural world will always occur *within time* (Philoponus, *In Physicorum*, 867, 22). However, since the parallel existence of the Universe and time is accepted with the Universe having been created *ex nihilo* as a result of divine activity (Philoponus, *De aeternitate mundi*, 343, 6-9), then the creation of time must correspondingly be attributed to God. Therefore, it is impossible to speak about the existence of time without the prior creation of the Universe.

It is worthy to note that the acceptance of the simultaneous existence of time and the Universe is not an original thought of Philoponus, but it was a topic of study for the Church Fathers in the field of Christian thought; the Fathers clearly support the idea of the parallel presence of time and the Universe. More specifically, it is stressed in the work of Basil the Great (Basil of Caesarea) that God created the Universe in a timeless manner, outside of time (Basilius Theol., *In Haexaemeron*, 1, 6, 29). However, if creation takes place without requiring the existence of time, then time is born together with the Universe, hence it is defined by Basil as *"having the same origin with the world"* (Basilius Theol., *In Haexaemeron*, 1, 5, 20). In the same frame of reasoning, Saint Augustine argued that time and the centuries are mere results of the creation of the world by God. It is interesting that this unity of existence of time and the Universe is accepted since the twentieth century by modern physics, which speaks explicitly about "spacetime": an event or phenomenon is described in terms of spacetime (Danezis, E. & Theodossiou, E., 1999).

The relation between time and the Universe beyond their *creatio ex nihilo* has, according to both Philoponus and modern physics, yet another parameter, that of the revolution of celestial bodies, through which time is determined and measured (Philoponus, *De aeternitate mundi*, 8, 15). Philoponus in his work considers motion as interwoven with time: according to his own phrasing, *"every movement is within time"* (Philoponus, *In Physicorum*, 869, 34). However, despite the fact that Philoponus connects in his work time with motion, he does not proceed to their identification; he merely notes that time is a manner of defining motion (Philoponus, *In Physicorum*, 711, 14-16). Consequently, both time and the Universe are merely *"measured the one through the other"* (Philoponus, *In Aristotelis Categoriae Commentarium*, 783, 4), a fact that denotes not only their parallel existence, but also the ability of the one to define the other through the process of measurement. From this, Philoponus draws the conclusion that in reality time is a *"number of movement"* (Philoponus, *In Physicorum*, 723,14-17), adopting at this point the exact Aristotelian teaching, which insists that time is number of motion (Aristotle, *Physica*, 251b, 12). Philoponus defines time as the *measure of the movement of heavenly bodies*, or, more simply, as *measure of movement*. Therefore, motion is not defined as "visible time", but on the contrary it is a characteristic subject of it in measurement. This view of Philoponus certainly describes the manner through which humans perceive the flow of time, as he perceives the day, the night and the succession of the seasons. The realization of all these phenomena, which gives rise to our perception of time, is based on the motion (rotation) of the Earth around its own axis and of its revolving motion around the Sun.

As a conclusion from what Philoponus writes about time, the researcher of his work should keep in mind i) the parallel existence of time and the Universe and ii) The possibility to define time via the motions of the celestial bodies. Therefore, the observation of the Sun, the Moon, and even the planets of the Solar System, makes humans capable of perceiving time.

3. Perception of time by human

Philoponus, commenting on Aristotle's work *Physica* (*Physics*), attempted to answer the question whether the absence of an observer who records the motion means also absence of time. The Aristotelian system for time consists of three factors:

a) The numbered (motion),
b) The soul, i.e. the observer who measures the motion.
c) The result of the measurement of motion (time).

Thus, if the soul-observer is absent, there will be no measurement and consequently no time, since it is the result of the measurement (Aristotle, *Physica*, 223a, 24-27).

Philoponus, following closely the Aristotelian teaching on time, suggests that *"when the soul is removed, time is removed together with it"* (Philoponus, *In Physicorum*, 775, 12). The use of the term *psyche* (soul) in this case has no metaphysical meaning, since this term is directly connected with the existence of time, which is a result of the observation and measurement of motion. Hence, Philoponus separates the physical event of motion from the mental activity of its measurement, exactly as Aristotle did before him.

Can, however, one speak about time without the existence of observers? Before the appearance of human on Earth (and probably of other creatures in the Universe), as it is natural, no observer was present in order to record the motions of celestial bodies, therefore time should not exist as a mental product. On the contrary there is continuous motion, which is evidenced in both the structural elements of the Universe's matter and the binary star systems. As a logical imperative, therefore, before the appearance of human Earth was also moving around the Sun and around its own axis, with only difference that these motions had not been recorded by observers. Thus, it is obvious that without some mental action there is only motion without time being mentioned (Kalachanis, 2011).

Philoponus realizes that the perception of time by the soul presupposes the additional determination of a point of reference, which he calls the *nyn* ("now"), an entity he assumes has no duration, but is merely a mental section of a time span corresponding to the present. This is the reason for which the 'now' is a part of the motion that is *"instantaneous"* (Philoponus, *In Categoriae*, 46, 19) and has no flow, while it is also considered by our philosopher as *generating agent of time* (Philoponus *De aeternitate mundi*, 727, 21), as it participates in its definition (Philoponus, *In Physicorum*, 721, 24-26). This view of Philoponus is totally based on the Aristotelian teaching, in which time is defined as a succession of "nows" (Aristoteles, *Physica*, 219b, 12), which are not time themselves but they participate in time's measurement. Therefore, the "nows" are a 'convention' in order to perceive the differentiation of the past from the future.

The notion of *nyn* had been supported by Aristotle, who suggested that it is a "middle point" (*mesòtes*) used as a basis to determine the end of time past and the beginning of the future (Aristotle, *Physica*, 251b, 25-29) (Figure 1). It is worthy to note that even the structure of time and space accepted by Newton and Galileo was exactly a present that extends in space, which separated the past from the future (Luminet, 2006).

Figure 2 presents the flow of time, which can be mentally cut into infinitesimal points (t_i). Aristotle, in order to demonstrate that the "nows" do not compose the time, likened them to the points of a line: As the line (the dimension of length) is not composed of points (which are dimensionless), but of a continuity, similarly time is not composed of "nows", but it is characterized by a continuous flow, which is perceived by human physiology as a flow towards the future (Aristotle, *Physica*, 241a, 2-4). The continuous flow of time towards the future corresponds directly, as we know today, to the thermodynamical "arrow of time". According to the second law of thermodynamics, the entropy in an isolated system, which expresses quantitatively the disorder or randomness of the system, never decreases as time passes. Entropy in isolated systems can only increase. Consequently, any asymmetry that characterizes a system can inform about telling apart the past from the future states-moments of the system.

From all the above we can draw the conclusion that the "now" can be characterized by the *"putting together in order infinitesimal time moments that are no themselves time, for time has a continuous and unbreakable flow"* (Georgoulis, 2000). In other words, the successive "nows" have no real existence, being just ideal sections of the flow of time.

Hence, based on the possibility to divide time into instantaneous moments, Philoponus, following Aristotle, studies the flow of time. For this purpose, he defines on the time flow two points he calls *proteron* (prior, t_1) and *hysteron* (posterior, t_2). These two points can be measured through the existence of *nyn*. These two points are actually two separate "nows", between which lies a time span.

During this time span (t_1, t_2), shown in Figure 3, the soul-observer records a motion (flow), which is perceived as time (Aristotle, *Physica*, 219a, 22-25). Therefore, the perception of time by the soul presupposes the determination of the notions of *proteron* and *hysteron*, between which motion takes place (Philoponus, *In Physicorum*, 720, 26). The 'prior' and the "posterior" certainly do not possess an objective existence, since they are points of reference, on which our conscience is based in order to perceive motion. They are, essentially, two *nyn* that define a time span, during which some motion or activity has taken place.

If, for example, with the aid of a clock we set as *proteron* the 6th hour of the morning and *hysteron* the 10th hour of the same morning, our planet has covered a certain part of its orbit around the Sun, while at the same time it rotates around its own axis by approximately 60 degrees. Our conscience perceives this motion as time.

Consequently, the notion of time is a mental process of the observer, who records the motion based on points of reference, called *nyn* ("nows").

4. The notion of observer in the special theory of relativity

The special theory of relativity revised in a radical way the classical Newtonian formulations of the notions of space and time, which prevailed in the natural sciences until the early twentieth century. Moreover, the introduction of quantum mechanical notions, mostly of the notion of the probabilistic viewing of the material world created contradictions and overthrew the deterministic picture of the world that had been cultivated by classical physics. The 'dead end' in this case appeared with the experiments of Michelson-Morley in combination with Maxwell's electrodynamics. The solution of the problem was given by Einstein with the formulation of the two postulates of special relativity:

1. The Principle of Relativity – The natural laws are the same for all systems in uniform linear motion relative to each other (inertial systems).
2. The Principle of Invariant Light Speed – Light is always propagated in empty space with a definite velocity (speed) c, which is independent of the state of motion of the emitting body and is measured to be the same in all inertial systems.

Essentially, special relativity was based upon the notion of the (inertial) observer (something that immediately determines the necessity of the existence of an inertial system of reference), because the observer, as in John Philoponus, is the factor that determines the manner of measurement and the value of the quantities of space and time. In classical Newtonian physics time flows according to a unique clock, i.e. with a unique temporal flow that is the same for all observers in all inertial systems imaginable. Time, and hence the expressions 'simultaneously', 'earlier', 'later', are absolute independently of the inertial frame of reference of the observer (Einstein, A. and Infeld, L., 1940). This, however, is not the case in special relativity. The answer to questions such as: *"if two events that occur in different locations are simultaneous or not"* (Young, 1994) is not unique, but it depends on the state of motion of the observer. The time span between two events is different for different systems of reference and each observer perceives the flow of time depending on the system of reference he resides. The notion of time, therefore, is not uniquely defined, but it depends on the "aspect", the system of reference of the observer. Two observers will perceive in a different way the time span or the dimension of length and they will measure different values for them when the one observer moves relative to the other. Thus, it is logical that certain events regarded by one observer as simultaneous are not simultaneous for another. These facts lead to the conclusion that time is a relative quantity, which depends on the system of reference of the observer selected for its measurement.

In the special theory of relativity time is a quantity that can dilate while length (in the sense of the dimension parallel to the direction of motion) contracts. The mathematical relations that describe these phenomena are:

$$\text{Time dilation:} \quad \Delta t = \frac{\Delta t_0}{\sqrt{1-\frac{u^2}{c^2}}}$$

$$\text{Length contraction:} \quad l = l_0\sqrt{1-\frac{u^2}{c^2}}$$

where:
Δt_0: the time interval between two events that occur at the same point in space in a certain reference system.
Δt: the time interval between the events as it is observed/measured in the reference system that moves at a speed u with respect to the first system.
l_0: the length between two points as measured in the motionless system.
l: the length between two points as measured in the reference system that moves at a speed u with respect to the first.

u: the speed of motion of the one reference system with respect to the other.
c: the speed of light c = 2.998 × 10^9 m/sec, a value that is the same for all inertial systems of reference and independent of the motion of the light source.

Using the Lorentz transformation it is possible to correlate the spacetime coordinates of an event (as recorded by an observer) from two different reference systems, moving relative to one another at a constant velocity (u). The mathematical relations of the transformation of the spacetime components:

x-component: $$x' = \frac{x - ut}{\sqrt{1 - \frac{u^2}{c^2}}}$$

y-component: $y' = y$

z-component: $z' = z$

t-component: $$t' = \frac{t - ux/c^2}{\sqrt{1 - \frac{u^2}{c^2}}}$$

The notion of absolute time that exists in classical mechanics does not exist in relativity theory. The values of the spacetime coordinates of an event depend on the reference system of the observer, but the quantity $c^2t^2 - x^2 - y^2 - z^2$ remains constant (invariant under the Lorentz transformation).

5. The notion of observer in the general theory of relativity

The general theory of relativity was developed in order to answer the question of the extension of special relativity to non-inertial systems of reference. The notions of space and time of special relativity are modified, resulting in a 'curved; and continuous spacetime. The curved spacetime is a consequence of the equivalence principle, according to which gravity forces are equivalent to inertial forces (e.g. the centrifugal force) and thus the gravitational field is a special dynamical field of inertia: all bodies in such fields get the same acceleration (Panos, 2002). General relativity as a generalization of special relativity was not based upon the notion of the 'observer' on inertial reference systems, but upon a more general notion of 'observer' for each system moving in any possible way, e.g. rotating.

Another fundamental element of the general theory of relativity is the concept of spacetime that presents a curvature depending on the mass. When the concentration of mass is very large, time flows at a considerably slower pace. Also, in special cases in which the gravity field tends to infinity, for example below the Schwarzschild radius of black holes, while time as perceived by a hypothetical traveler heading towards the point singularity of the black hole is finite, an external observer recording the event from the Earth will receive 'frozen' images until the signal disappears as the astronaut will be absorbed by the singularity. In general relativity, therefore, although the role of the observer is present in the perception of time, the observation *per se* differs depending on the gravitational effects on spacetime due to its curving by the presence of mass.

The analysis of the spacetime continuum is extended to observers on accelerating systems, and because of these systems the laws governing the gravitational force are re-formulated. Under the influence of gravity forces alone, the trajectories of all bodies, $x^\mu(s)$ in the four-dimensional continuum of spacetime are called geodesics. Geodesics are the curves of minimum length that connect two points of spacetime; an equivalent mathematical definition is that they are the lines along which the "directional" derivative of their tangential directions is zero:

$$\frac{D}{Ds}\left(\frac{dx^\mu}{ds}\right) = 0\,.$$

Einstein's equations describe the properties of spacetime in a gravitational field (its curvature), however they do not explain how bodies will move in that curved space.

In order to overcome this difficulty, the simplest way is to say that particles and light rays move in spacetime in the most efficient manner. If a body is to move from point A to point B, the trajectory it will follow will be the shortest distance that connects these two spacetime points. Since space is curved, this trajectory will be a geodesic line. The particular equations that must be solved in order to determine the shortest trajectory that will be followed by a particle of matter or a light ray are called geodesic equations. Several problems in general relativity are solved through the simultaneous solution of Einstein's field equations and the geodesic equations.

The general relativity equations for gravity are:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\frac{8\pi G}{c^4} T_{\mu\nu}$$

where:

$R_{\mu\nu}$ is the Ricci curvature tensor

$R = R_{\mu}^{\mu}$ is the scalar curvature

It should be noted that the solutions of the non-linear differential Einstein's equations are usually approximate.

6. Conclusions

The key common element emerging from this study is the definitive importance of the observer in the perception of time. Already in the 6th century, John Philoponus, following the Aristotelian teaching, theorized that time is a measurement of motion, which is defined on the basis of reference points that denote the present and were called *nyn* ('nows'). Using the 'nows' human mind can tell apart the past from the present. Despite the fact of the existence of such points, Philoponus stressed that time is characterized by a continuous and unbreakable flow. In the special theory of relativity the determination of time depends on the system of reference upon which the observer is stationed; on the contrary, in the general theory of relativity the observer perceives time in a way that depends on the gravitational influence exerted by mass on spacetime.

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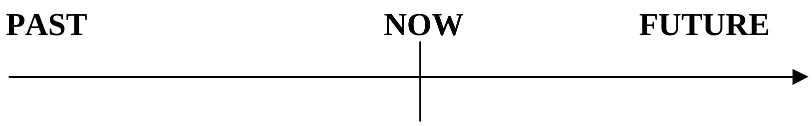

Figure 1

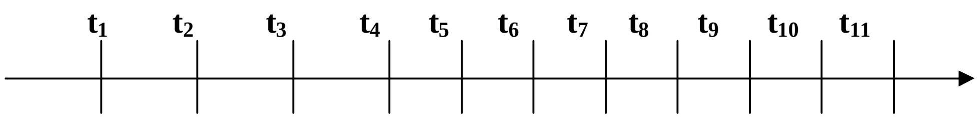

Figure 2

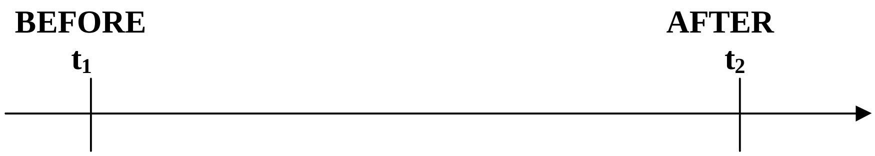

Figure 3