Aus dem Institut für Medizinische Psychologie

Institute der Ludwig-Maximilians-Universität München

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Temporally Scattered Brain: Neural Mechanism Apprehending the Paradox of the Discrete and Continuous Flow of Consciousness

Dissertation
zum Erwerb des Doktorgrades der Humanbiologie
an der Medizinischen Fakultät der
Ludwig-Maximilians-Universität zu München

vorgelegt von

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aus

Torbateheydarieh, Iran

Jahr

2021

Mit Genehmigung der Medizinischen Fakultät
der Universität München

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Tag der mündlichen Prüfung:

14.06.2021

"Freedom from the desire for an answer is essential to the understanding of a problem."

Jiddu Krishnamurti
(1895-1986)

To all who took my hands…To all who released them,

To all who believed me…To all who ignored me.

To all who brought me here…To all!

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Zusammenfassung

In dieser Dissertation werden offene Fragen über „Bewußtsein“ aus neurowissenschaftlicher, psychologischer und auch philosophischer Sicht erörtert. Es geht insbesondere darum, wie in traditionellen und modernen Ansätzen die Beziehung von zeitlicher Informations-Verarbeitung und Repräsentationen im Bewußtsein konzipiert werden. In einer historischen Aufarbeitung wird gezeigt, dass Zeit als mentale Kategorie in der psychologischen und neurowissenschaftlichen Forschung lange eher vernachlässigt worden ist, was sich erst jetzt zu ändern scheint. Wie wichtig Informations-Verarbeitung im Zeitbereich für ein besseres Verständnis von Bewußtseinsprozessen ist, wird herausgearbeitet, denn alle Verhaltensweisen und alles bewußte Erleben haben notwendigerweise eine zeitliche Charakteristik. Die grundsätzliche aber bisher nicht hinreichend beantwortete Frage ist, ob diese Charakteristik, die Informations-Verarbeitung in der Zeit, als kontinuierlich oder als diskret zu verstehen ist. Neue Befunde legen nahe, dass so genannte „Zeitfenster“ bestimmter Dauer notwendig sind, um neuronale Informations-Verarbeitung zu ermöglichen, damit Bewußtseinsprozesse überhaupt entstehen können. Wenn aber diskrete Zeitfenster notwendig sind, dann stellt sich die weitere Frage, wie es paradoxerweise zum subjektiven Eindruck einer zeitlichen Kontinuität zum Beispiel in der Wahrnehmung kommen kann. Das Erleben zeitlicher Kontinuität bezieht sich nicht nur auf Prozesse der Wahrnehmng und des Erlebens, sondern auch auf den viel weiteren Rahmen der Kontinuität personaler Identität. Es wird darauf hingewiesen, dass diese Kontinuität bei bestimmten Erkrankungen oder veränderten Bewußtseinszuständen verloren gehen kann. Ein derartiger Verlust legt nahe, dass es aktive Mechanismen auf neuronaler Ebene geben sollte, die personale Identität über die Zeit hinweg erzeugen. Es mußt gleichsam ein „Klebstoff“ vermutet werden, der zeitlich Diskretes in anschauliche Kontinuität verwandelt. Mechanismen, die hierfür in Frage kommen könnten, sind bisher nicht bekannt. Ein erster Versuch zur Aufklärung dieser Frage wird mit einem fMRT-Experiment gemacht, in dem visuelle und auditive Vorstellungen untersucht werden. Hier zeigt sich, dass in beiden Modalitäten gemeinsame neuronale Aktivierungen in bestimmten Hirnstrukturen zu beobachten sind, was möglicherweise einen ersten Hinweis auf die Erzeugung von anschaulicher Kontinuität geben könnte. Des weiteren wird am Ende der Arbeit auf die Bedeutung des Reafferenzprinzips hingewiesen, das vielleicht einen neuen Ansatz zum besseren Verständnis mancher Phänomene wie des Déjà Vu geben könnte, wenn man in dieses klassische Prinzip einen Zeitfaktor integriert, was bisher theoretisch nicht geschehen ist. Während der Fokus der Arbeit auf theoretischen Konzepten zu Zeit und Bewußtsein im psychologischen, neurowissenschaftlichen und philosophischen Kontext liegt, werden auch Bezüge zu den Künsten, der Dichtkunst und der Musik, offen gelegt. Dies soll darauf hinweisen, dass die Beziehung zwischen der „Zeit des Menschen“ und dem bewußten Erleben ein Menschheitsthema ist, das über den wissenschhaftlichen Rahmen hinaus weist.

A b s t r a c t

In this dissertation open questions about “consciousness” are discussed from a psychological, neuroscientific and also philosophical perspective. In particular, it is described how the relationship between temporal information processing and conscious representations is conceived in traditional and modern approaches. In a historical review it is shown that time as a mental category has been neglected for a long time in psychological and neuroscientific research, although this is changing recently. The importance of temporal information processing for a better understanding of conscious processes is analyzed because any behavior and all subjective experiences necessarily have a temporal characteristic. There is, however, a basic and still open question whether this characteristic, i.e., temporal information processing, is continuous or discrete. New research suggests that “time windows” of specific durations are necessary in neural information processing being the basis for conscious representations. If, however, discrete time windows are necessary the question arises how paradoxically the subjective impression of temporal continuity for instance in perception is possible. The impression of temporal continuity refers, however, not only to processes of perception and experience, but in a broader context also to the continuity of personal identity. It is indicated that this continuity can break down in certain diseases or in altered states of consciousness. Such losses suggest the existence of active mechanisms on the neural level which allow for the creation of personal identity across time. Some kind of “glue” has to be suspected that transforms what is temporally discrete into apparent continuity. Potential mechanisms for this transformation are still not known. A first attempt is made to answer this question with an fMRI-experiment in which visual and auditory images are analyzed. For both modalities’ common activations in certain brain regions are observed which possibly might be a first indication about a mechanism creating apparent continuity. At the end of the dissertation the importance of the reafference principle is stressed as it may provide a new perspective towards a better understanding of some phenomena like Déja Vu, if one includes in this classical principle a temporal factor which theoretically has not been done yet. Although the focus of the dissertation lies on theoretical concepts of time and consciousness within a psychological, neuroscientific and philosophical context, some links to the arts like poetry and music are made transparent. This shall indicate that the relationship between the “time of humans” and conscious experiences is a topic of humankind that goes beyond the scientific frame.

INTRODUCTION

A symphony must be like the world. It must contain everything.

— Gustav Mahler

What if we were all conscious of only one moment— a moment without past and future. Now imagine all these moments were not connected together, each existing in an isolation from all other moments. Imagine that life was full of discrete frames with pauses and darkness between. It seems hard to imagine this state of being because we perceive life so fluidly and our mind travels back and forth in time so smoothly, like a boat on a sleek surface of a river. Our entire life consists of a vast number of such moments of being, which become and pass away in a ceaseless stream. But, the neurologic ward of every hospital and psychiatry clinics have lots of stories to tell about these consciousness disturbances. Each of these scenarios narrate something about how brains have been evolved to provide all organisms with valuable consciousness and how we neglect the challenging procedure for our brains to create such a complicated smooth flow of conscious living. We are riding on the saddle of life so elegantly that sometimes we forget that we have seated on the brink of a sword. Each kind of consciousness disruptions can lead to a tragedy for all of us.

Most people do not wander about our nature. Some of us do not notice that what precious things we have and appreciate having them. We are all adapted by our routine life and we are unaware of complex underlying process of existence. However, in the level of expertise, we brain researchers have not grasped many problems fully. We have spent our lives with the desire for the answers. Among many questions, the brain and the problem of consciousness have occupied our mind. Yet, when we intend to grab what consciousness is, it dissolves like fog into the air. The knotty situation of understanding what consciousness is reminds me a quotation from Augustine in his book *Confessions (400 AD)* about the time: "What is time then? If nobody asks me, I know; but if I were desirous to explain it to one that should ask me, plainly I do not know." In this statement, it seems to me Augustine implies the difficulty of speaking about time and I believe that we are all in the same situation when the question of consciousness arises.

Why has the pursuit of consciousness nature been so cumbersome? Do the remaining ideas of the previous scientists and philosophers have prevented us from progress in consciousness studies? Is our brain the seat of consciousness? Just as a symphony with different musical instruments scattered on the stage, does the brain with all neurons form consciousness? Who is the conductor of this consciousness symphony? Do brains need a conductor to create a unified conscious perception? These are not new questions and approximately two millennia of human history have not given us a satisfying answer. Indeed, our fundamental beliefs about consciousness have not changed that much. Systematic thinking about consciousness

was inflamed by Descartes in 17th century and put us in front of two contradictory concepts—that the mind works independently of the brain or it is a byproduct of brain's interconnected neurons. In fact, these notions are still with us and they shaped a *world's knot* as Schopenhauer calls it.

In the beginning of new century, studying consciousness swollen again. After years oppression of behaviorist psychologists and putting consciousness in a non-scientific realm, the topic of consciousness blossomed fervently. Many researchers have established a passionate interest in consciousness. Over the short period of its existence, consciousness studies have become extensive. Nowadays, scholars use 'consciousness studies' as an umbrella term for the multidisciplinary study of consciousness in different fields such as neuroscience, psychology, philosophy, artificial intelligence, and linguistics. As I write this introduction, Google Scholar website shows me over four million books and articles with "consciousness" word in their contents! Nevertheless, despite the contemporary enthusiasm of understanding consciousness and how the brain builds this edifice, there are a few generally accepted consensuses.

This dissertation is not about consciousness per se. It is comprised of many themes. For me, consciousness is like a symphony and as Gustav Mahler says: *A symphony must be like the world. It must contain everything.* I believe that consciousness should be viewed from different perspectives and it should contain many theories. Despite millions of publications about consciousness, I found it redundant to focus on what consciousness is and the mainstream topics. Instead, I try to narrow the topic down to one of the problems of consciousness which has not been considered seriously by past and modern thinkers. My main concentration is on the relationship of time and consciousness (also the brain) and the way these concepts interplay together. I believe that time as a denominator factor has been ignored by brain scientists.

But, why should we consider the concept of time seriously? Why should we know about time? And why should we study time and its relationship to the brain (or, state of being conscious)? To answer these questions, first and foremost, time embraces matter. All beings to which the very consciousness relates were born and will die in the vessel of time—it contains everything. We occur in time, we cope with time and we are the product of time, so to speak. Time is also identified with consciousness— all of our behaviors and contents of consciousness have been tied in a temporal zone.

Our thoughts, our movements, our perception are extended in time and it seems to me the relationship of time and consciousness is inseparable. In other words, time is the constituents blocks of consciousness. Furthermore, the time awareness is a psychological fact. It is one of the innate natures of humans. As an idea that can be spoken, we have the sense of passing time and the capacity to recall it. This seems to come from childhood. Children first start talking about the present, and then references to a brief future are quickly accompanied by references to a brief past. To make the answer a little poetic, I borrow a quotation from Santiago Ramón y Cajal, the leading 19th century neuroscientist who says that "as long as our brain is a mystery, the universe, the reflection of the structure of the brain will also be a mystery." Yet, I say as long as time and its relationship to the brain is a mystery, our consciousness and its contents will be also a mystery.

Nevertheless, is the time that we live in, or live through, and its relationship with our consciousness, continuous, like a stream of river or is it discrete and bumpy, like beads on a string? Is the stream of awareness consisting of an insistently of momentary awareness acts, or is it like a river inherently uninterrupted, sleek, non-stop phenomenon? How is the thread of continuity in time preserved? Whence this continuity of time between episodes come from?

David Hume, in eighteenth century, believed in the idea that time is comprised of discrete moments and mind is 'nothing but a bundle or collection of different perceptions, which succeed each other with an inconceivable rapidity, and are in a perceptual flux and moments.' He argues that:

"It is still true, that every distinct perception, which enters into the composition of the mind, is a distinct existence, and is different, and distinguishable, and separable from every other perception, either contemporary or successive."

In another argument, he takes our different feelings which they do not occur simultaneously and they succeed each other as a good illustration for proving the discrete form of consciousness. His debate goes on in this way:

"If any impression gives rise to the idea of self, that impression must continue invariably the same, through the whole course of our lives; since self is supposed to exist after that manner. But there is no impression constant and invariable. Pain and pleasure, grief and joy, passions and sensations succeed each other, and never all exist at the same time. It cannot, therefore, be from any of these impressions, or from any other, that the idea of self is derived; and consequently, there is no such idea."

On the other side, for William James, the 'Humean view' as he calls it in his book *Principles of Psychology (1890)* is both vexing and counterintuitive as a start. In one of the chapters of his book on *'the stream of consciousness'* he emphasizes on the concept of continuity of consciousness. He believes that to the owner of consciousness, it seems always continuous without rupture, fracture, or division. Although the content of consciousness changes repeatedly, we switch seamlessly from one thought to the next, without disruptions or bumps. As the chapter of James's book touts, 'the stream of consciousness' entitles that our thoughts flow smoothly. He puts it in this way:

''Consciousness, then, does not appear to itself chopped up in bits. Such words as 'chain' or 'train' do not describe it fitly as it presents itself in the first instance. It is nothing jointed; it flows."

Though, he doubts on his idea and wonders whether consciousness is really continuous, or is it an illusion similar to that of the zoetrope? Zoetropes were very well-liked instruments in James's period. These devices contained a disc on which displaying a rapid sequence of a single, steadily picture such as acrobat in motion and plants growing. These images show progressive segments of the motion in an illusory manner, with multiple sketches tossed by a rapid succession at a critical pace. It appears that James's doubt about the continuity of consciousness was arisen by the function of zoetrope in that period. The illusory movements of still pictures which conveyed motion were very paradoxical and contradictory in the mind of James. However, the zoetrope demonstrated that static images could be combined in the brain to eventually lead to an illusion of continuous motion.

In line of this argument, later on, Bergson in his book *Creative Evolution (1907)*, devotes a very long part to *'The Cinematographical Mechanism of Thought and the Mechanistic Illusion.'* Although when Bergson talks about 'cinematography' as a crucial mechanism of brain and mind, he implies a very significant sort of cinematography in which 'snapshots' are not septate from each other but naturally connected.

In another book of him, *Time and Free Will (1889)*, he mentions that those perceptual instants are 'permeated one another or 'melted into', like the notes in a piece of music (although there are some empty and succeeding beats of a metronome, we hear it interconnected and uninterrupted). For him, the foundation on which continuity is built is the originality of time or heterogeneity.

Putting our predecessor's discussions on discrete or continuous form of consciousness aside for moment (I will scrutinize all these opinions in the upcoming chapters), preserving our identity *(self)* in time is another enigma. I suppose that we cannot consider the nature of 'self-continuity' without deliberating the character of time. Time is entirely a subjective concept for the *self*. There is no relation between subjective time and clock time. From the perspective of many philosophers and physicists, as an autonomous body, time does not exist. It is a mind-dependent concept entirely related to the mutual interrelationship of experience, learning, and intrinsic characteristics of personality (e.g. Adolf Grünbaum's 'mind dependent' theory of time (1963) or Einstein's theories of relativity (1915).

For our *self* to be maintained, time has quality. As Whitrow (1980) has argued, we do not perceive time, per se, but rather what goes on in time, and the experience of time has both quality and quantity. With change in time, the self evolves. The self, likewise, merely finds itself in relation to time. Besides, for some analytical philosophers like Eroll. E. Harris (1976) time may not have an objective entity because of immeasurability of subjective elapsed time. That is, to inquire how quickly the last five minutes have passed in terms of clock units is nonsensical. However, it is not absurd to tell "very fast" or "faster than usually". But, if we take a rod and begin to measure the elapsed five minutes, it would be a trivial effort.

Everything has an underlying mechanism; physicists take this truth down to the quantum level. In brain science we encounter the same situation. We should take things apart to see what makes them a beat. It is necessary to know the parts and see how they interact together. There is no doubt that in some way the parts of our brain work cooperatively to fabricate our mental states and behaviors. However, sometimes they do not function properly. Consciousness disorders, such as schizophrenia, for example, occur when structures that typically underwrite conscious perception are unavailable or impaired. In this dissertation, I will consider all these concepts meticulously. The chapters discussed in this volume draw our attention to the cutting-edge notion of our existence— time and brain. I have endeavored to provide the reader with at least two sides of an enigma and leaves the planetary open for future investigations. This dissertation demonstrates the importance of time in contemporary neuroscientific and psychological exertions which have been neglected for centuries.

In this volume, I have tried to keep the explanations about time, brain and consciousness clear and simple, without losing sight of the fundamental points of these complex phenomena. I hope, by the end of this dissertation, the readers may come to have a fuller appreciation of this wonderful device of life— the brain— and enjoy this journey into what is not only the most complex but, for me at least, also the most fascinating object in the universe.

The goal of this dissertation is to examine and, to the scope possible, revitalize some underrepresented questions. The plan of this volume is as follows:

In chapter 1, I explore mainly on the technical and the entity of consciousness as an enigmatic concept. Having provided what I mean by consciousness, I offer the readers the definitions, discussions, objections and ideas in this realm. I go briefly through a historical

overview on consciousness studies in this realm and discuss their limitations and problems. Besides, I take a look on conceptual debates on the nature of consciousness in recent years. I argue on understanding the neuroscientific approaches of consciousness and give my opinions about different interpretations of consciousness. In fact, it is a delicate matter and I want to make sure I adopt the right tone in telling my opinions.

In chapter 2, I begin with elucidation of the concept of time. Then, I enter to some discussions and have an overview in different schools, ideas and theories in understanding time in the course of history. I provide readers with many theories and also objections from scientists' and philosophers' opinion. The last part of this chapter belongs to the models of time.

In Chapter 3, I allocate the space to phenomenology of time (time and being). This section is mostly comprised of existentialist philosophers' opinion on understanding time from being's perspective. It is mostly concentrated on the interpretation of time from philosophers' perspective such as Husserl, Heidegger, Bergson and others.

Chapter 4 is devoted to the concept of time from psychological and neuroscientific perspective. I introduce different models of time and its relationship to the brain. I bring lots of evidence in recent brain science discoveries that all organisms are crammed with different clocks. We have been enfolded in time and all of our actions are determined by a timing system. I investigate different clocks of our brain from motor timing and subjective time up to circadian rhythms.

In chapter 5, I go through this enigmatic question whether our subjective time flow is continuous like a river or discrete and bumpy. I provide the reader with lots of evidence that subjective time flow is discrete.

In chapter 6, I investigate another conundrum: if we admit that out flow of subjective time (consciousness flow) is discrete, what is the neuronal basis of gluing these temporally scattered system? If all the brain activities have been scattered temporally, what does connect them all? What is the thread? Whence does this sleek, floating experience of ours come, although the underlying structure is gappy?

In chapter 7, another question arises: how does we preserve our self-continuity? How could it be that our identity is preserved although its underlying basis is discrete? How is it possible that after awakening from a long sleep, every morning we recognize ourselves in the mirror as 'I am that'? In this chapter, I introduce my hypothesis.

In chapter 8, I have penned about my personal views on doing science and the complications of our scientific scotoma.

1

C O N S C I O U S N E S S

O hidden under the dove's wing,
hidden in the turtle's breast,
Under the palm tree at noon,
Under the running water,
At the still point of the turning world,
O hidden.

— T.S.Eliot

1.1. What Is Consciousness?

That we have mind is strange indeed, for it is conscious. We have astonishingly flamboyant perceptions of the world. Moreover, the question of how we perceive the world and what consciousness is do not have any easy, obvious answers. Nor is there at present any consensus that could be regarded as a received standpoint on what it is in the scientific and philosophical community. It seems that it is impossible to define consciousness neither in terms of necessary and sufficient conditions nor in the Aristotelian way of genus and differentia. Besides, we have also some linguistic barriers which makes it difficult to give a noncircular verbal definition.

In this complication, although there are a number of different ways to describe consciousness, I prefer to take the standpoint of neuroscientist Francis Crick and Christof Koch. They begin their article, *'Towards a neurobiological theory of consciousness'* by asserting that they do not give a precise definition of consciousness since 'everyone has a rough idea of what is meant by consciousness' (Crick and Koch, 1990). I believe that since we are conscious of our existence, finding a definition about consciousness seems to me unnecessary. So, wherever I use consciousness in this volume, I mean 'the state of being conscious' as all of us experience it.

Consciousness as a frame of our perceptions is an epistemological inquiry. Which metaphysical status we settle determines how we pursue the concept. Consciousness is largely interrelated with a core question of how we view the universe, including ourselves.

The desire to address the question of consciousness is not per se a need, but an attempt to strengthen our understanding of how the brain functions. In a nutshell, by "consciousness" I mean our modes of conscious experience, consisting of all modes of consciousness, thought or feeling, sensory or non-sensory, veridical or hallucinatory. In the widest-range context conceivable, it is envisaged.

For me, the fact that consciousness is enigmatic is that we have not understood its fundamental processes well. It is exceedingly difficult to discern, from the focal point of ignorance, which problems are potentially more difficult and which can be solved. As Churchland (1996) proposes, "learn the science, do the science, (then) see what happens". Therefore, in this chapter, I restrict myself to a brief historical view and some debates in consciousness studies by introducing some schools of thought in this realm. I think that there is no subject matter in the history of philosophy and science as fascinating as historical record of human in understanding of consciousness.

1.2. A Historical Overview on Consciousness Studies

Nature in her unfathomable designs has mixed us of clay and flame, of brain and mind, that the two things hang indubitably together and determine each other's being, but how or why, no mortal may ever know.

— William James

Who is running the 'consciousness' show? How does the brain, with all its diverse and scattered functions, create the edifice of a unified sense of 'self'? How is it possible that the brain (matter) with phenomenal character states (non-matter) is responsible for the development of consciousness? How could it be that the brain produces "technicolor phenomenology of consciousness" (McGinn, 1991) or it works like "the appearance of Djinn when Aladdin rubbed his lamp" (T. H. Huxley, 1866)? How can we explain the missing link between these two different concepts? In other words, is there a mechanism which provides an explanatory link between the subjective and the objective? What might this mechanism be and how does it function? How could it help us in understanding the rest of ourselves? We presently have no idea. But, what did our predecessor scholars think about this mysterious phenomenon and these profound questions?

These are some perplexing questions which have occupied the great minds for centuries. Nevertheless, what we know is that consciousness popped up a time in our evolution history and although we do not know where and when it happened exactly, it became one of the outstanding impediments in scientific understanding of our universe in the modern era. Consciousness is a relatively new idea. It is a word as now largely used in lots of contexts. It has become a "suitcase word" as Marvin Minsky would call it because it is packed full of various meanings. The word "consciousness" was invented in its modern sense merely in mid-1600s by René Descartes. It also has roots in the Greek word *oida*— "to have seen or perceived and hence to know"—and the Latin equivalent *scio*, "to know." Nonetheless, the ancients did not have a plain view of consciousness. Among the ancients, there was interest in how the mind works, where thoughts come from, but most of the answers wrapped up

concluding that mental life was the outcome of an immaterial spirit. Naturally, when consciousness is perceived as immaterial spirit, it would be difficult to start pondering about underlying physical mechanisms!

Like many modern questions which have origin in classical epoch in Greece, the burgeoning remarks to consciousness traces back to Hippocrates and Aristotle writings. Discussion on the location of mind (or soul, or spirit or in a modern term 'consciousness') swapped between the heart and the brain. While Aristotle pondered that the mind resides in the heart, it was Galen (A.D 129-99) who first developed experimental proof for localizing the mind in the brain. In Galen's experiment on Barbary macaque, squeezing the brain of the animal caused unconsciousness whilst squeezing the heart allowed the animal to remain conscious. Thus, he concluded that the brain is the seat of consciousness. He also localized the soul to the ventricles of the brain. During the Renaissance, the Galenic theory of brain as the locus of consciousness (mind) was expanded. Leonardo Da Vinci and Vesalius began careful examinations of the human brain itself (Galen's experiments were restricted to animals). The history of brain science is a cemetery of well-intentioned efforts to lucidly establish the cerebral base of consciousness.

The modern era of neuroscience began by experiments of the British anatomist Thomas Willis (1621-1675). He similarly localized consciousness to the nerves of the brain and again emphasized on the ventricles. That the ventricles became the first choice for the seat of soul was owing to their wing-shaped form. In the turn of 16th century, the most famous historical statement of the relationship of brain to the mind was expressed by Rene Descartes. He proposed this religious notion by separating the mind *res cogitas* and body *res extensa* mechanism from each other. He became the father of modern mind-body dualism. He found a new place for soul – pineal gland – a small nubbin of matter above the brain stem.

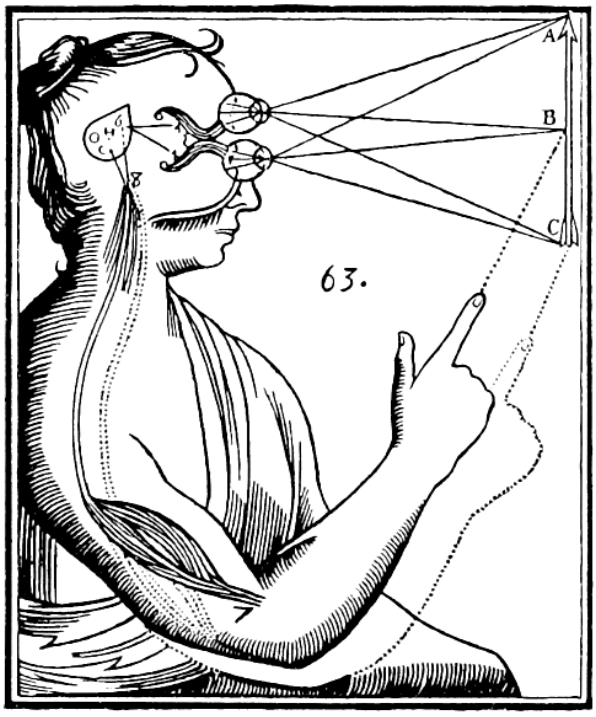


Figure 1*: René Descartes' drawing of mind/body dualism. Descartes believed inputs were passed on by the sensory organs to the pineal gland in the brain and from there to the immaterial spirit.*

However, the tendency towards Descartes dualism was not restricted to his epoch. The innovative curiosity in consciousness studies has ignited a blazing surge of text on the mind-body problem. Although believing in dualism seems heretic in scientific contexts, the division of mind and matter is still perceived as one of the most challenging questions about how mind can arise from matter, and solving the first person and third-person views, has remained the hardest problems. The question of consciousness rose again if a dominion of the mental is equal to the dominion of the physical, in which case a kind of Cartesian dualism reappeared. We can see that some neuroscientists like Sir John Eccles in 20th century have a strong defense of what appears to be a new dualism or by, a proposal from Roger Sperry that consciousness is an evolving with causal properties which could be comprehended if we really knew the emergent brain processes organized by consciousness.

Some believe that Descartes by expansion of dualism placed consciousness outside of the scientific realm. However, it should be mentioned that Descartes was the first who brought about the neural correlates of consciousness. In his era which many were driven by Aristotelian thoughts and considered brain as a cooling system of the body, he recognized that the brain has a significant role for sensory input and motor output, but this did not construct it the basis of mind. He pondered that animals do not possess mind because he saw them as unthinking machines for which a brain was sufficient. From Descartes viewpoint, consciousness was a state of mind, while the brain plays a role in nonconscious processes and link matter and mind. Physical bodies have an impact on sensory organs and create motion in the body's nervous system. These motions are translated into mind's experience of different sensory feelings like color, pressure, sound and other sensations. Besides, these motions are transferred to *pineal gland* where rational soul and accordingly conscious experience or idea are created.

Although Descartes was wrong about the function of pineal gland in the brain, he drew the attention of many thinkers about the importance of the brain as the center of perception in creating our world. While Descartes tried to connect physical and mental to each other, Baruch Spinoza (1632-1677) proposed the idea that the mental and physical are different aspects of the same substance. In philosophy of mind, Spinoza's *dual aspect theory* or *dual aspect monism* which is also akin to neutral monism is the opinion that the mental and the physical are two ways defining the same elements, which are themselves "neutral", that is, neither physical nor mental. In other words, he claimed that the mental and physical are two basically different entities and the universe consists of only one kind of stuff which is neither mental nor physical.

By blossoming German philosophers' idealism such as Gottfried Wilhelm Leibniz, consciousness was seen from a different view. Idealism school proclaims that consciousness belongs to all entities which exist and the material world is just an illusion. The doctrine of omnipresent consciousness in matter roots in a thought called *panpsychism* which ascribes consciousness as a completely autonomous entity of the materialistic elements of the world. For them, consciousness is tightly connected to our mental life and we are unable to explain it by physical sciences. Leibniz' metaphor (1714) between the brain and the mill elaborates this topic better:

"Suppose that there be a machine, the structure of which produces thinking, feeling, and perceiving; imagine this machine enlarged but preserving the same proportions, so that you can enter it as if it were a mill. This being supposed, you might visit it inside; but what would you observe there? Nothing but parts which push and move each other, and never anything that could explain perception."

A century later, Thomas Huxley (1866) deems the consciousness the same:

"How it is that anything so remarkable as a state of consciousness comes about as a result of irritating nervous tissue, is just as unaccountable as the appearance of the Djin, when Aladdin rubbed his lamp."

Ideas about consciousness at the last three hundred years were plentiful but confusing. It seems to me walking into the history of the study of consciousness is frightening. It is tormented with the complex and abstract works of philosophers. However, it took a while till intelligent Scottish philosopher, David Hume, who was already irritated by philosophy's "endless disputes" turns the idea of consciousness towards a futuristic view. He supposed that the idea of the essence of supernatural mind to the body was a misconception, and absolutely silly. Likewise, he found out that the ancients' moral and natural philosophy is entirely conceptual and more based on invention than on experience. According to him, most of the questions asked by philosophers could not be resolved using logic, mathematics, and pure reason. Therefore, we need more methodological equipment for answering complex questions like consciousness. By his efforts, we enter into an empirical horizon of understanding consciousness from his era on. He was one of the pioneers of establishing a clarified glare at consciousness. Some deem him to be the father of cognitive science.

However, in my opinion, the thoughts of Hume about past philosophers do not underestimate the position of philosophers who have led us to think about the mind, the soul, and consciousness. They have had a major impact since ancient times on developing our cognitive toolkit to understand the world's dynamic phenomena. It is worth saying that hypothesizing about consciousness was not restricted to philosophers and scientists. Interestingly, artists and literary figures also in the course of history have played their role in expressing their views about consciousness. In literature, literary figures such as James Joyce, T. S. Eliot, and Virginia Woolf have commented on this enigmatic phenomenon.

Also, in painting, for instance, Michelangelo Buonarroti´s piece of art (1475–1564), *The Creation of Adam (Figure 1.2)*, is one of them. Different authors have proposed that the shape of God depicted in giving reason to Adam resembles to the sagittal section of a human brain (Meshberger, 1990; Paluzzi *et al*., 2007; Suk and Tamargo, 2010).

As the closing remark in this section, in pursuing what consciousness is, Julian Jaynes in his provocative book *The Origin of Consciousness in the Breakdown of the Bicameral Mind (1977)* has raised the significant question based on the argument in the time of Homer that what we now construe as consciousness was contemplated to be the voices of the gods. The Greeks may actually have "heard" the voices as some schizophrenic patients do today. The separate roles of the two hemispheres enter into Jaynes' conjectures about the bicameral mind which the left hemisphere orders the right one to do some actions. In any case, consciousness has become such a complicated issue that takes us to a far metaphorical imagination. For me, Jaynes' theory on consciousness is a prototypical case which exhibits how difficult is to say what exactly consciousness is.

***Figure 2**: Michelangelo Buonarroti (1475–1564), The Creation of Adam (1511–1512), fresco, Sistine Chapel, Vatican.*

1.3. Conceptual Debates on the Nature of Consciousness in our Modern Era

My soul is a hidden orchestra…All I hear is the music.

— Fernando Pessoa

With all the considerate efforts in understanding consciousness in the history, nonetheless, it is still a noticeable mystery for philosophy and science in modern age. The fact that some philosophers like Dennett deny its existence, or others (Chalmers) solve it by attribution of as yet unidentified irreducible properties, or claim it is beyond the limits of human understanding (McGinn). In this section, I intend to look briefly at these thoughts. Although it is a widespread theme, I find it necessitous to mention selected of the most important ones here.

Some reflect that the phenomenon of consciousness is weird and there exists a gap between conscious experience and its scientific explanation. This view has waged by this sense that the subjective experience is a non-reducible phenomenon. This view has become one of the most important issues in consciousness studies. It concentrates on the concept of qualia—individual instances of subjective quality, conscious experience such as feeling sad, or smelling coffee, or getting angry. But, the notion that these private subjective feelings (raw feelings) are just such a change in cells' firing seems does engender a kind of intellectual discomfort. For many it is like a category mistake, something similar to saying that the number 5 is identical to that apple over there, or that justice is nothing but cement mixed with wood fiber.

This notion brought about a philosophical problem in consciousness which has challenged the great minds. For each such inherently conscious mental state, there exist a subjective viewpoint that goes along with it. In the philosophical terminology, it is said "what it's like" proposition (Nagel, 1974). "What it's like" or what is so called qualia seems to be a challenge in the scientific understanding of consciousness. From many theorists' perspective, demystifying qualia can open the doors in decoding what consciousness is. There are lots of behavioral studies that try to harness qualia but from some thinkers' view like Nagel (1974) and Searle (1992) any effort to understand the subjective experience of consciousness under behavioral studies will disregard its very nature— its subjective and phenomenological feel.

Why is qualia so important? It is deemed that *it* is one the three properties of consciousness: *qualia, spatial geometric properties, and temporal properties*. Although many theories have tried to explain spatial geometric properties and temporal properties of consciousness, the impasse of how qualia can be explained in a physical aspect is fundamentally difficult. There is something it's like subjectively to feel pain, to smell burnt food, to taste a lemon, to feel delighted. Let me take a specific situation to exemplify the problem. Suppose that you are beside a beach and lying in the sun with closed eyes. You have not a watchful in the world. Everything seems good. Unexpectedly you feel severe pain in your left leg— a hornet stings you. There is something it's like for you at this particularly luckless instant. There is a unique experience you are bearing, not related for its existence to anyone else seeing or thinking about your state. But the pain you are feeling— that specific pain— is private to you. No one else could have that particular pain. However, it could be conceived that someone else might have a pain that felt just like your pain, but only you could have that very pain. What is true for all mental objects of experience is that these items of experience cannot be shared. Your visual images or feel of tickles are just belong to you, for example.

Another problem of qualia which is called *perspectival subjectivity* defies physicalism— the viewpoint that the universe, including all that is mental, is totally physical. Phenomenally speaking, conscious states are perspectival. So, in order to comprehend them fully, it requires accepting a certain experiential point of view. Nonetheless, physical states are not perspectival in this way. For example, a blind and deaf person cannot experience lightning by sight or hearing or he has not seen gold, but he is capable of understanding what it is, namely a certain kind of electrical discharge between clouds or the element of gold with atomic number 79. Frank Jackson in his article *"What Mary Didn't Know" (1986)* brings a *Gedankenexperiment* to argue against physicalism and defending perspectival conscious states. He depicts the situation as follows:

"Mary is a brilliant scientist who is, for whatever reason, forced to investigate the world from a black and white room via a black and white television monitor. She specializes in the neurophysiology of vision and acquires, let us suppose, all the physical information there is to obtain about what goes on when we see ripe tomatoes, or the sky, and use terms like "red", "blue", and so on. She discovers, for example, just which wavelength combinations from the sky stimulate the retina, and exactly how this produces via the central nervous system the contraction of the vocal cords and expulsion of air from the lungs that results in the uttering of the sentence "The sky is blue". ... What will happen when Mary is released from her black and white room or is given a color television monitor? Will she learn anything or not?"

Jackson, in the rest of his article maintains that physicalism would be false if Mary does learn something new upon experiencing color. His argument seems like an attack to the physicalist assertion about the completeness of physical explanations of mental states. In other words, can Mary know what the experience of red is like if she has never seen red

although she knew everything about the science of color perception? Jackson replies in this way that, yes, she would learn something new via experience, and henceforth, physicalism is false. Jackson continues:

"It seems just obvious that she will learn something about the world and our visual experience of it. But then it is inescapable that her previous knowledge was incomplete. But she had all the physical information. Ergo there is more to have than that, and Physicalism is false."

In a nutshell, the protagonists of irreducibility of qualia claim that if we want to elucidate consciousness in physical world, it appears incorrect to pinpoint conscious experiences with matter. However, the answer to this objection can be defended in this way: apart from what exactly matter is and the controversies around it, matter is not the merely kind of physical unit. For example, electromagnetism is also an unquestionable fragment of the physical world or who can claim that wind although it is not seen does not belong to the physical world?

Among these debates of physicalism, reductionism and non-reductionism (see more schools in consciousness in figure 3), another school of thought was emerged. It is one of the more prevalent views in current thinking about consciousness which is called *functionalism*. This method has grown out of the major advances in computer science over the past fifty years. The term describes an umbrella overview for ideas promoted with enthusiasm by many researchers (e.g., Minsky, 1985; Hardcastle, 1996; Dennett, 1991; Churchland, 1996). However, it remains an argumentative point of view and other researchers argue strongly against it (Penrose, 1989, 1994; Searle, 1992; McGinn, 1997), or at least suggest the necessity of alternate methods (Stapp, 1997; Scott, 1995; Baars, 1996; Garson, 1996; Flanagan, 1997; van Gelder, 1997). For instance, John Searle's *Chines Room* argument (1982) is against this notion. The Chinese room argument holds that a digital computer performing a program cannot be exhibited to have a "mind", "understanding" or "consciousness", regardless of how intelligently or human-like the program may make the computer act. Searle's *Gedankenexperiment* begins with this assumed premise: suppose that artificial intelligence research has succeeded in building a computer that behaves as if it comprehends Chinese. It takes Chinese characters as input and, by following the commands of a computer program, produces other Chinese characters, which it gives as output. Let's suppose that this computer accomplishes its task so convincingly that it easily passes the *Turing test*: it persuades a human Chinese speaker that the program is itself a Chinese speaker. To all of the questions that the person asks, it makes fitting responses, such that any Chinese speaker would be persuaded that they are talking to another Chinese-speaking human being. The question Searle wants to answer is this: does the machine literally "comprehend" Chinese? Or, is it only simulating the capability to understand Chinese?

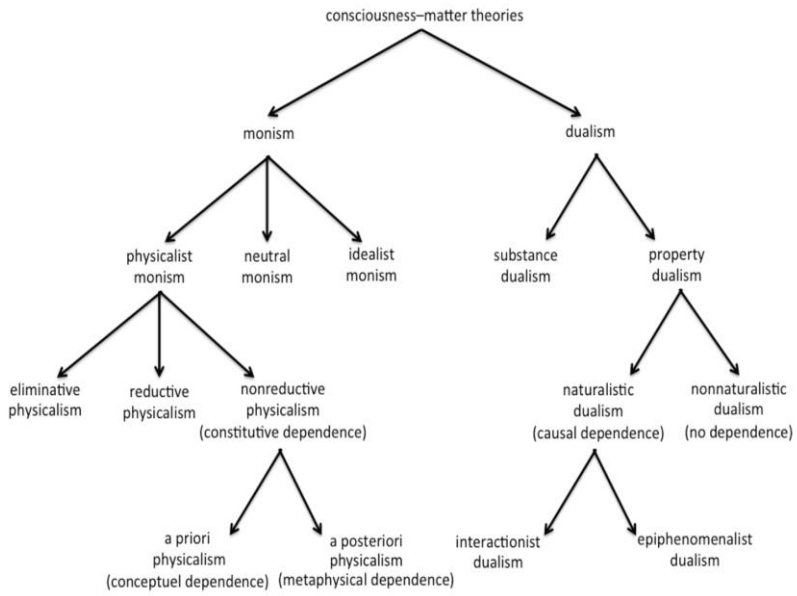


Figure 3: *A diagram of the most important schools in consciousness studies*

1.4. New Era and Different Interpretations of Consciousness

Change is scientific, progress is ethical; change is indubitable, whereas progress is a matter of controversy.

—Bertrand Russell

Having said about some of the conceptual tackles in consciousness, it is worth mentioning that as will become more obvious gradually, the concept of consciousness has profoundly altered over the past twenty-five hundred years. Its fictional beginnings and its current implication have little to prepare with each other. After years of exile, pondering about human consciousness has been revitalized into the circle of scientific discourses. There is a feeling that it might be a fortune to attain something progressive in elucidating the nature of this mysterious phenomenon. It looks like there is a good reason to be optimist. Recent progresses in neuroscience, philosophy, and the social and human sciences have offered a tremendous bulk of new theoretical and empirical results. However, there is often more heat than light—more endeavors to win the argument than to uncover truth. It is inevitable that we humans requisite a new way to ponder about the problems.

If one looks at the consciousness studies, one sees that two fundamental approaches of consciousness studies are by now broadly documented: the studies on passive situations, as when we lie back and attend to music, and the studies on active, as when we are in a creative mental condition— for instance, make plans and dream how to undertake them. However,

the classification between active and passive is never accurate because sometimes we can actively pursue experiences that result in passive realizations. Nonetheless, bulk of the literature on consciousness has been allotted to the passive mode, such as studies on meditation, examining the depths of consciousness or in quest of consciousness expansion. On contrast, the studies on active mode is concerned with decision making issues and acting upon them. In fact, planning is a major part of mental life, whether the plan is simple or long-range in its completion. In both cases, consciousness plays a vigorous role as the person looks ahead, instigates action, and presses on against deterrents and limits.

Today, we see consciousness completely different from our ancestors. Development in brain imaging technology and new approaches in our scientific paths have given us a great opportunity to scrutinize deeper into this experience. For example, we can find the trace of consciousness even from pre-birth period. Many studies have shown that organs of action and perception for a conscious communication with others shape in the body and brain of a fetus, and there exist signs that fetal senses are active and alert before birth (Trevarthen, 2004; Trevarthen *et al*., 2006). Biological analysis on the embryos of birds and mammals have also shown that there are anatomical groundings for a future moveable and intelligent life (Lecanuet *et al.,* 1995).

Moreover, there are lots of scientific proofs assert that although infants cannot speak, they are conscious completely of their surroundings. Infants are capable to perceive actively and involve emotionally with the consciousness of other individuals. They acquire a cultural "human sense" of things by cooperating in humorous ways with others (Reddy, 2003). If we take intention in the earliest movements of an infant, we notice that conscious awareness is adjusted to detect actions that have certain purposes in the outside world. Infants seemingly sense that their bodies are separate from that outside world. We have many scientific marks that infants are capable to detect objects and persons as completely different entities and accordingly they have different practices. Last but not least, their innate capability in acquiring language— a narrative tool for a child's straight, socially adapted self-consciousness and personality is another proof in existing consciousness even from the beginning steps of life.

Furthermore, modern technologies have paved the way to study animal consciousness. In the search of consciousness for animals, there have been discussing whether animals possess consciousness or not. There is also no evidently settled upon sense in which the term "consciousness" is used for them. However, two regular senses of consciousness are not in argument when applied to animals: when a creature is awake rather than asleep or in a coma, and the rudimentary ability of organisms to perceive and thus react to selected potentials of their environments. When one goes beyond these two consciousness definitions for animals and add more qualities for consciousness like speech and language, an author like Descartes denies speech and language to animals, and consequently denies consciousness to them. In our modern realm, epistemological belief upon language as an indicator of consciousness was a fortified supporter of philosophers such as Dennett (1969, 1995, and 1997) to disprove that animals are conscious in anything like the same logic that humans are. Or, if one takes Davidsonian view on consciousness (1975) in denying intentional states to animals, one would likely agree that animals do not hold consciousness either.

Two further logics that cause controversy when consciousness applied to animal are *phenomenal consciousness/qualia* (Block, 1995) and *self-consciousness*. As I mentioned before, *phenomenal consciousness* denotes to the qualitative, subjective, experiential, or phenomenological features of a conscious experience. It is sometimes also identified as qualia. As I mentioned before, the question of qualia raised by Nagel (1974) to focus on the fact that

how it is like to be something. Nagel argues that we should investigate our capacity to discern, imagine, or explain in scientific terms what it's like to be a bat.

Self-consciousness refers to an organism's capacity for recognizing its own mental states and it is used as an acid test to know which animals alongside humans are conscious *(The Distribution Question).* The capacity for self-consciousness is thoroughly interconnected to issues about "theory of mind" in nonhuman animals— whether any animals are capable of ascribing mental states to others. Problems about self-consciousness and theory of mind in animals are a matter of scientific dispute, with the most devotion to chimpanzees and to a limited extent on the other great apes. Despite controversies, mirror test is utilized as a scientific tool in understanding self-consciousness in primates. However, it was notorious that primates would use mirrors to examine their images, but Gallup (1970) advanced a procedure to allow a scientific basis of whether it is only the mirror per se that is appealing to the animal inspecting it, or whether it is the mirror image for the animal itself that is the object of interest. The efforts in understanding the enigma of self-consciousness showed that chimpanzees and orangutans are the only primates who "passed" the test. Reiss and Marino (2001) have also provided some evidence of mirror self-recognition in two bottlenose dolphins. Likewise, it is likely that the mirror test is not an appropriate test for theory of mind and self-consciousness in most species. It is argued that because the "mirror test" depends specifically on the ability to match motor to visual information, an ability that may not have evolved in a majority of species, for example those species that depend on chemical or auditory signals. Lastly, in pursuing the scientific investigation of animal consciousness, the methodological suggestions have been strongly criticized, often observed as anthropomorphic.

Evolutionary speaking, if we take conscious experience as a natural feature of organisms then there is an evolutionary description for its existence in those organisms. However, not all the properties of an organism are a feature. As Stephen J. Gould (1987) famously maintained that the panda's "thumb" and the shape of human chins are not suited in the category of an organism's traits. He argues that not all traits are formed by a process of adaptation through natural selection. Some attributes were formed by chance— mutation or drift— or by self-organization. It should be mentioned that some of us who have a casual familiarity with evolutionary theory think that all evolutionary explanations are adaptation explanations— that every developed trait aims for adaptation. There is no evidence that supports the idea that the evolution of consciousness roots in the adaptively environment purpose. For instance, there is no evidence that creatures with consciousness were more fit than their nonconscious ones, or consciousness has given them any advantages at all. Now, if we assume that consciousness is a natural biological feature and If it is complex system or is segment of a complex system, then there will be an adaptation explanation for it, or for some of its qualities.

Another clue about the emergence of consciousness which today's development in science has given us comes from sleep studies. Finding about different sleep phases brings to this conclusion that not only consciousness happens in a graded mode and emphasizes the state dependent nature of it, but also it advocates how small a portion of brain activation is dedicated to consciousness and that most brain activity is not associated with consciousness. It is apparent that consciousness demands a very specific set of neurophysiological conditions for its manifestation.

1.5. Towards the Neuroscientific Approaches of Consciousness

For sure, the holy grail of science is to find consciousness in the brain, but trust me, it would have been found by now if there were such a thing to find.

— Michael S. Gazzaniga

Progress in neuroscience has come from focusing on the body (matter) rather than the mind (non-matter). New ways of understanding brain have brought us to this conclusion that there is no such a thing as an independent mind (*res cogitas*, in Descartes terminology sense). Mind is a mere product of the electro-chemical interactions in the brain. By taking this idea as a roadmap, neuroscientific approaches to consciousness was blossomed. In this context, the neuronal correlates of consciousness are thought of as a state-dependent form of some indefinite complex, adaptive, and highly interconnected biological system. In search of consciousness, different theories tried to explain how these packs of neurons end up into this edifice of conscious perception. In this section, I briefly introduce some of them. Indeed, it is a widespread topic which I do not intend to go in detail.

One of the neuroscientific possibilities about consciousness is *The Global Neuronal Workspace Theory.* This model was introduced by Bernard Baars in 1988. He first proposed this theory in his book *A Cognitive Theory of Consciousness* as a cognitive/computational model. According to this model, the contents of consciousness are contained in a global workspace, a central processor used to make the contents of consciousness globally *accessible* to multiple systems including long-term memory, motor, evaluational, attentional and perceptual structures. When these particular processors need to broadcast information to the rest of the system, they do so by sending this information to the workspace, which performs as a kind of blackboard for the rest of the system, available to all the other processors. In fact, the global neuronal workspace theory joins access to brain construction. Baars uses this system to address many features of human cognition, and to clarify a number of distinctions between conscious and unconscious cognitive functions.

The Neural Darwinism Model of Consciousness was proposed by Gerald Edelman in 1989. He believed that consciousness is necessitated by reentrant interactions among neuronal populations in the thalamocortical structure (the 'dynamic core'). These collaborations, which permit high-order discernments among possible core states, present selective advantages on organisms possessing them by connecting current perceptual events to a past history of value-dependent learning.

Daniel Dennett' *Multiple Drafts Model of Consciousness* pursues a physicalist view in consciousness. He suggested this notion in his book *Consciousness Explained*, published in 1991. He views consciousness as a product of a large information processing. For him, consciousness is a property that emerges from lots of dispersed quasi-understanding in a large system.

In 1987, Ray Jackendoff published *Consciousness and the Computational Mind*. The "intermediate level" theory of him was born by an important question: where, in the current of information, does consciousness arise? Jackendoff's answer is simple. He observed that many of our mental capabilities, including our senses and our language faculty, are structured hierarchically. In each of these hierarchies, it makes sense to ponder about low-, intermediate-, and high-level processing structures. We break down errands into phases.

Appealing to prevailing models of these phases, Jackendoff observed that the intermediate level seems to be favoured with respect to consciousness. Consciousness seems to ascend in intermediate-level processing systems and not elsewhere.

Another doctrine which stands on a modest hypothesis explains consciousness as the outcome of definite types of information-processing computations, physically apprehended by the hardware of the brain. This theory claims that although information processing theory on consciousness is unable to describe consciousness per se, we can understand more about consciousness by diving deeper into what the information processing is in nature. According to this theory, we cannot call a system conscious that is merely capable of distinguishing certain states. As a matter of fact, to be conscious, that organism should be able to combine information in a spatiotemporal basis in order to form a consistent and unitary representation of the real world. For instance, imagine we are looking at a beautiful piece of art in a painting gallery. We cannot autonomously see parts of an image and voluntarily reduce or increase the speed of our perception but always the image as an integrated whole. As you noticed, according to this theory colors are not independent of shapes, shapes are not independent of objects and objects are not independent of their localization in any aspect. This hypothesis so called *The Information Integration Theory (IIT)* in understanding consciousness roots in Tononi´s approach. He argues that in pursuing consciousness we should address two vital issues: firstly, we should establish a condition which demonstrates to what extent an organism or a system has consciousness. More vividly, we need to know which parts of the brain are necessarily vital in emergence of consciousness and accordingly ask why these assigned parts are important and others not. Secondly, understanding the levels of consciousness and what kind an organism can have. From Tononi's viewpoint, if we are able to solve the second issue which utterly relates to quality or content of consciousness, we can understand this phenomenon better.

Orchestrated Objective Reduction Theory was first put forward in the midst 1990s by theoretical physicist Roger Penrose and anesthesiologist and psychologist Stuart Hameroff. They assume that consciousness originates at the quantum level inside neurons, rather than the orthodox view that it is an outcome of connections between neurons. In brief, they proclaim (inspired by David Bohm's quantum theory) that the mechanism is held to be a quantum procedure called objective reduction that is orchestrated by cellular structures called microtubules. Hameroff proposed that microtubules were suitable candidates for quantum processing. Microtubules are made up of tubulin protein subunits. The tubulin protein dimers of the microtubules have hydrophobic pockets that may hold delocalized π electrons. Although there are lots of objections on the foundations of this theory, it has become one of the considerate hypotheses about emergence of consciousness. For many antagonists, the brain is an unsuitable place to host the quantum phenomena required by the theory, since it is considered too "warm, wet and noisy" to avoid decoherence.

Having said a brief explanation of the most important consciousness theories, up to now, it appears to us that these definitions and theories have left many scientists and philosophers still unsatisfied about what consciousness indeed is. Metaphorically speaking, consciousness like a fortress under siege of thousand warriors has defied many thinkers to provide convincing solutions about many mysterious questions of it. There are still some scholars who are wondering whether we are "over-intellectualizing" consciousness. Should we accept that some high-level cognitive functions are necessarily tangled to consciousness? Or, are we ignoring the experiential component (what is like to be conscious?) and got lost in terms and vocabularies which have recently created by philosophers? Or, should we explain subjective experience of consciousness (qualia) to open the mysterious gates of consciousness? Or more

radically speaking, the modern terms created by some philosophers and scientists like hard problem of consciousness, phenomenal consciousness, qualia, etc., are just the epistemological artifact and we should revise more about what philosophers have innovated in this era.

More metaphorically speaking, we see the sun rising in the east and setting in the west. It seems a satisfying convention that works very well for us to go through the day, even though we know well that that is not what is really happening at all. We know it truly the planet is rotating us into and out of view of the sun. We are happy to go with the appearance of things, even though the reality is completely a different phenomenon. In other words, we know we might be so far from a correct understanding of what consciousness is, but we should notice that it has given us a power to survive and nourish in our evolutionary story. It has become an integral part of us and so near that we do not need to feel it so far. As Wittgenstein reminds us, 'nothing appears to be so close and intimate and, at the same time, so distant and unreachable from us than our own conscious mind'. In overall, I tried to convey this message that until everyone innately knows what it means to be conscious, there is no need to make it very complicated and philosophical. However, I am completely mindful that there is still the amazing impression of an unbridgeable gap between our internal conscious world and what is out there. Nevertheless, the efforts we will have in our future scientific investigations in pursuing consciousness tell the story of how the human mind courageously tries to build a walkable bridge over this gap.

As the last comments on this section, it is worth noting that although science endeavors to explain all phenomena of the world, to get busy elucidating, we need fundamentally to be clear on what are the phenomena which need explaining. That is, we need to be clear on our *explananda* before beginning our explanatory initiative. I suppose that in the search of consciousness and its studies, we have fallen into the trap of what I call "elephanted consciousness." I borrow this metaphor from one of the mystical stories of Rumi (mystic poet of 13th century). He brings the elephant metaphor in his seminal book *Masnavi* to show us that how we see the world and mentioning the limits of our perception: The elephant story is about six men trying to feel an elephant in a dark room, each attempting to describe it. One reflects of the tail as a rope, another the leg as a column, the elephant's trunk as a hose, the body as a wall, the tusks as swords and the sixth ponders that the ear is a large fan. This has been a major problem for consciousness scholars. Besides that, I think one of the problems with illuminating consciousness is that we all think we are consciousness specialists, and have very strong theories about it, just because we have experienced it. Nonetheless, we should not be that much disappointed. We are on the path to understanding that consciousness is not a "thing." It is the result of a process rooted in an architecture, just as a democracy is not a thing but the consequence of a process.

2

T I M E

Time present and time past
Are both perhaps present in time future
And time future contained in time past.
If all time is eternally present
All time is unredeemable.
What might have been is an abstraction
Remaining a perpetual possibility
Only in a world of speculation…
Time past and time future
What might have been and what has been
Point to one end, which is always present.

—T.S.Eliot

2.1. What Is Time?

I suppose that when we ponder what "consciousness" is seems like asking what "time" is. It seems to me these two concepts are highly interconnected. Both are enigmatic and daunting. But, what is time? It is one of the most difficult questions of mankind from ancient epoch which have brought lots of paradoxes. In fact, asking any question of an abstract term with "what is…" in order to define it can lead to paradoxical answers. Nevertheless, men have always taken advantage of a ideal, a imaginary, exterior sign scale upon which they are able to represent their conception of what time is. There are lots of examples which prove it: the arrangements of heavenly bodies, the natural stages of agriculture, and the assumed actions of the gods. Despite those efforts to understand time, it appears that it is still one of the most challenging and vague issues in modern era.

Then, is time what the clock says? Though it is a challenging question, as soon as we sincerely start thinking about time, we realize that there is no subject more mysterious and ineffable than it. 'Ineffable' is a mainly good approach to put it: it means 'beyond words.' It is hard to get commenced in thinking about time, because it is hard even to put our thoughts about time into words. The most frequent quote from Augustine in the literature which has been penned about time conveys this sense better. Augustine writes, "What then is time? If no one asks me, I know; if I want to explain it to a questioner, I do not know" (Augustine, 400 AD). According to Augustine, he knows what time is as long as he is not forced to give it a verbal definition. It appears that for him time is an idea that we appear to understand, but once we strive to explain time itself, it gives rise to contradictions.

In line of this argument, let me leave "what time is" at this for the moment and instead ask, what is a chair? Let's try to define it. You may say that a chair is something to sit on, or something with four legs, a back to relax on. A pony also has four legs and a back that I can be on. You have noticed this fact that we cannot define objects in a very clear-cut way. There is always an unquestionable amount of ambiguity involved. What we name a chair is a common-sense feeling of what a chair ought to be. I have a notion of a chair, but it is very hard to exactly describe what a chair is. It seems to me the situation of time definition is the same. But, why don't we know what time is while we tell, save, waste and kill every bit of it in our life? It must be something peculiar that it constantly evades from our grasp. Nonetheless, is putting the label of 'something' to time, right? I do not think so because time cannot, for all its influence over our lives, an entity. Can we say it is a 'forceful nonentity'? Perhaps. I suppose that I am going too far in this sense.

Ineffability of time may lead us to this idea that we completely negate the concept. Nevertheless, you may not believe in the concept of time, but the changing essence of the universe implies that there is such a thing as *time*. By rising and acting, everything undergoes distortions. There is some eternalness behind the transition in all these situations, and this is true of the stream, the marsh, the rising tree, and many other beings. We often call this change as passage of time. Heraclitus, the Greek philosopher, is the pioneer of this idea that change is the underlying basis of our Universe. He believed that '*there is nothing permanent except change*.' In plain words, he means that everything is constantly changing and change is the only reality in nature. Individuals are never the same, changing in some way from minute to minute to day-to-day experiences. There is a *flow* in which the world continuously changes and no two situations are exactly the same. It appears that every mortal change ceaselessly in the river of time.

Having motioned the flow of time, it should be said that no one disagrees that there is some fundamental, wide-spread concept of time which has penetrated into our daily life. Sometimes, in our subjective experiences, understanding time is limited to theme of temporal passage. We use metaphors for time in order to embrace this mysterious phenomenon. These metaphors of time are used in different languages with colorful cultural backgrounds. We represent time as space in metaphors such as "detached past or future," a "long time ago", or we conceive time as vigor: "Time reached me and I couldn't complete the mission", or we give time personage in such metaphors as "Time will say…". However, most of them are sterile to convey the essence of this concept.

Fairly speaking, the problem of understanding time has been under intense deliberation throughout history of mankind and the problem brought up many other questions rather solving it: is the passage of time real, or is it only a subjective feature of our experience? What is the nature of experiencing time? What contributes time its direction? Is travel in time possible? Is the future unwritten, and do our alternatives matter? Did time begin, and, if so,

how? What about the experimental sciences? What is the relationship between our experience of time and time as defined by the experimental sciences? How is understanding our experience of time relevant to understanding time itself? And many other questions

Gifted thinkers have been working on these questions for thousand years and they have done so much of the basis that makes things a lot clearer for us: from Aristotle's standpoint, time and change are two sides of the same coin— change and time are two interwoven concepts. For Descartes time is an infinite succession of durationless moments. Kant's version of time emphasizes on this notion that time is generated by counting numbers. Heidegger with borrowing the predecessors' notions of time with an eclectic manner, slips this statement that "time is number in the sense of counted nows". As you see, there are lots of these interpretations of time in the history of science and philosophy. But, could they be true?

We can summarize theories about the nature of time over centuries into three main camps: idealism, realism, and relationism. *Idealists* consider time as a merely subjective matter, and nothing in reality resembles to it. Time is a kind of notion in the mind, rather than a thing that can authentically be ascribed to nature. *Realists* argue that time is a real thing, a kind of underlying ground for events. They ponder about time as how events can be objectively correlated to each other. *Relationists* take the middle path; they believe that time is just a way of linking events to each other, but the relations it defines are real.

Let me set this forceful, changing and mysterious concept aside and have a historical overview on different contemplations of the gifted thinkers on the notion of time through history. It seems to me that being familiar with our predecessors' thoughts paves the way in understanding this enigmatic nonentity.

2.2. An Overview at the Notion of Time through History

Time and space are modes by which we think and not conditions in which we live.

—Einstein

All of us have heard these expressions that "time is money" or "time is gold". It looks like that time functions as a ruler to measure many things. We measure our personal trait by it ("I saved an amount of Euros in the last four years"); we measure our occupation by it (devastate instead of disassemble old apparatus since "time is money"). Our work agenda is time-limited. We unintentionally organize our free time, assuming to use so many minutes to telephone a workmate, to read a book, or to play with our offspring. We are too much involved in terms of time. Why are we so much concerned with time? It seems that it is not a concept which has been restricted to modern human. Human history is full of contemplation and compulsiveness about time.

By a closer look at the antique period, we are told that the majority of men were conscious of time. The ubiquitous and constant alternation of day and night, of the seasons, of birth, growth and death, of wakefulness and sleep, of the stars' lunar stages and trails, make it possible for a sense of time to be constructed in man. Besides, the least as well as the most

progressive human groups established ways of calculation and gauging the track of time. Early Egyptians' calendar shows that they framed an annual calendar of 365 days separated into three seasons and twelve months of thirty days plus five epagomenal days. The remaining devices from the archaeological finds such as shadow clocks, sundials and water or sand clepsydrae as well as the "diagonal" calendar or "star" clock from that period proves this thesis. Natural or even more trustworthy celestial occasions were utilized for controlling significant human events. For instance, the ancient Egyptians identified the heliacal escalating of Sirius as early as the Middle Kingdom (2100-1800 B.C.) and used it to signal the beginning of the year. The South African Bushmen, who dearth all efficient knowledge of astronomy, note the rising of Sirius and Canopus and estimate the progress of winter by their movement across the night sky. Indeed, ancient men thru the earth created to calculate the track of time by counting moons. And he still looks after, particularly in traditional activities of Muslims such as religious means in *Ramathan*.

In spite of Babylonians and Egyptians sophisticated time measurements, neither of them, except the Greek people who demonstrate any evidence of having perceived time. Ancient peoples, did not isolated time from its contents. For them time was qualitative, phenomenological, concrete interval or multiple. Time was not a neutral and abstract frame of reference. Time was its own contents. Events were not in time, they were times. Ancient Hebrew, for instance, did not have a word for time, but for season which it points in time, or eventful duration. The sentiments expressed in this passage from *Ecclesiastes 3. 1-13*, one of the 24 books of the *Old Testament (Hebrew Bible)*, might be the best examples for the above-mentioned claims:

To everything there is a season, and a time to every purpose under the heaven:

A time to be born, and a time to die; a time to plant, and a time to pluck up that which is planted;

A time to kill, and a time to heal; a time to break down, and a time to build up;

A time to weep, and a time to laugh; a time to mourn, and a time to dance;

A time to cast away stones, and a time to gather stones together; a time to embrace, and a time to refrain from embracing;

A time to get, and a time to lose; a time to keep, and a time to cast away;

A time to rend, and a time to sew; a time to keep silence, and a time to speak;

A time to love, and a time to hate; a time of war, and a time of peace.

Certain ancient Greeks took the most critical step towards such a philosophical view of time. In Plato's works, and in a more evolved state, in Aristotle, we find time analysis. Furthermore, we can see from the Greek poets that time was hypothesized into one entity, cosmological concept or deity, Chronos. In the view accredited to Pherecydes (mid-6th century B.C.) by Damascus, such a conception can be demonstrated:

"Pherecydes of Syros said that Zas always existed, and Chronos and Chtonie, as the three first principles ... and Chronos made out of his own seed fire and wind (or breath) and water..."

The poets of the next century had full godly and anthropomorphic characteristics of this divine entity, Chronos. It was all mastering for Sophocles period, it exposed and concealed everything. It taught man every science for Aeschylus. The best mentor, the supreme judge and the man's reliever were the time for Solon:

"Time is a god who makes rough ways smooth ..."

But, for Milesians— inhabitants of Miletus, an ancient Greek city in Anatolia, modern-day Turkey— time was not apprehended as determined, watchful entity, as gods. Here is the commencement of the de-deification of flora of time, the beginning of scientific scrutiny to time. Anaximander, a pre-Socratic Greek philosopher who belonged to Milesian school, puts the first steps in the de-deification and de-anthropomorphization of time. He believed that all coming-to-be from and all ceasing-to-be into the *apeiron*—cosmological theory created by Anaximander who believed the beginning or ultimate reality is eternal and infinite, or boundless *(apeiron)*—happen not in line with the force of time but on the basis of necessity. Time holds a role in the course of nature:

"And the source of coming-to-be for existing things is that into which destruction too, happens according to necessity; for they pay penalty and retribution to each other for their injustice according to the assessment of time ..."

However, if time was not deified, element, or form anymore, what was that? Ironically, Zeno of Elea, the pupil of Parmenides, who, like his master, denied the reality of time, had the most significant influence on such a conceptual development. Zeno was concerned with motion rather than time. Motion may be understood either as constant, hence indefinitely divisible, or as discontinuous, hence ultimately indivisible, Zeno thinking. Briefly, Zeno argued that movement must be endless and therefore impossible in continuous time and space – although that distance was minimal. The questions of existence and the essence of abstract time were posed by Zeno. Plato and Aristotle struggled to provide answers through various methods and successful steps.

For Parmenides, physical entities are timeless. He was praised or blamed for proclaiming that what is real can surpass time (there was a certain emphasis that epoch on the division between appearance and reality, and how appearances can be misleading). He argues against the reality of time in this way that due to innate of contradiction in temporal thoughts, reality cannot be temporal. So, in Parmenides term, what's wrong with these paradoxes? They are a "backwards turn" to use the Parmenides metaphor. If you affirm and refuse the same, you can't get anywhere. Contradictions strain to confirm and refute, so they really do neither. In other words, people often appear to believe what they perceive, but their views shift in time.
Parmenides' key strategy was to weed out fundamental inconsistencies in traditional beliefs in order to illuminate the true character of truth. Parmenides is regarded as an ardent rationalist, someone who has the desire to abandon intuition so that he can champion an a priori interpretation.

In accordance with F.M. Cornford (2003): "While Heraclitus is the prophet of a logo that cannot be pronounced in obvious contradictions only, Parmenides is the prophet of a logic that will not accept a side of inconsistency," the final conclusion of Parmenides is striking. He maintains:

"[I also hold you back from the way] on which mortals wander knowing nothing, two-headed; for helplessness guides the wandering thought in their breasts, and they are carried along, deaf and blind at once, dazed, undiscriminating hordes, who believe that to be and not to be are the same and not the same; and the path taken by them all is backward- turning."

Parmenides also uses a different argument against time. He believes that anything that could be thought of (or named) must always endure, since it could always be thought of. Finding everything which named all the time would weaken the concept of time because all "times" would be the same time. There would be no time, if there were no change because for him change is an illusion. For Parmenides, the link between time and change deceive us about the concept of time. He thought the reference is what always exists.

He considered that the reference needs to be effective in its current existence. Thus, if change is an illusion and accordingly time does not exist, what would time be? Parmenides would say that our experience of movement, change, and the passage of time is a projection of our own imperfect perception on reality. He believes that when we step back from what our senses are telling us and then we should begin reasoning whether our postulations really make sense. The world as it is in itself is a uniqueness: unitary, unchanging, perfect.

The ancient literature is full of these colorful explanations about the nature of time. Discussions about generation (genesis) of time can also be traced in Plato's work, *Timaeus*. In Timaeus, he argues that god designed the sun, the moon, and other stars and placed them in a circular orbit to generate the time. Thus, time obtained units by its parts, the days and nights, months and years. He claims that time would come to an end if these bodies would terminate their orbits. He also speaks of stars as the "instrument of times". It was Plato, to my knowledge, who labeled moving image as time by which baffled physics and bewildered philosophy. For Plato, it is time, or better to say the physical world, which belongs to the world of appearances; for in the physical world there are no true "comings into being", but only copies. The Athenian would be the copy of a type in general. More specifically, with the ordered universe time starts and stops being:

"... Time came into being together with the heaven, in order that, as they were brought into being together, so they may be dissolved together, if ever their dissolution should come to pass."

Likewise, for Plato, time is a mathematical concept and its mathematical fauna is unchangeable. Plato came to this idea by the motions of the planets:

"...In order that Time might be brought into being, Sun and Moon and five other stars – 'wanderers', as they are called - were made to define and preserve the numbers of Time."

While Plato denied the time truth, his contribution was important to the development of the idea. He considered time, for example, as the number or series of motions. In connecting time with number, it was noted that the need to allocate time not only as a definite but also as a consistent series was significant. Plato illustrated the time with a consistent flow at the beginning. For a time, he described a metric that was like planetary revolutions. Furthermore, Plato considered numbers an indivisible, distinct object. But how would temporal continuity is insured if time is a detached, inseparable whole? Currently, it could not be like that by this model. Plato proposed a different paradigm, which he called the "farther" principles of truth, to ensure the continuity of time. There is a circle in this system in which there is a continuous circumference.

By this description, time is now defined by circular planetary motions, which can participate in the circular attribute. They are thus basically continuous. In ancient Greek we have Aristotle as the champion of theorizing on the concept of time. Time is a thing inseparably linked with the awareness of the transition in the Aristotelian definition. He thought of time being fundamentally linked to change and movement. For him, change is real: things move from one place to another, seasons change, ice melts, and many other forms of change. He saw a liaison between time and change, but the nature of that relationship needs some clarification. In his works, he highlights the importance of change in time understanding. He maintains, "Not only are we measuring the change in terms of time, but the change in time, because they are defined by one another." Time and change are therefore two sides of the same coin. Aristotle was a pro-temporary camp who thought that time was a fundamental universe concept, and insisted on what "there are true enthusiasts."

Time is defined to a certain extent in the ideas of Plato for Aristotle. But between the two opinions there are great differences. This world has a temporal structure for Aristotle and therefore time is not just real, but vital. Aristotle explained the coming and passing not, as we do, with regard to movement in space and time, but with regard to the facts, triggers, ends, and shifts, comprising movement, as we understand what he called "local motion." These movements established the theoretical framework of Aristotle rather than time and space.

But what was the flora of such a local motion, he left unexplained. However, Aristotle vigilantly scrutinized his predecessors' views and tried to formulate an approximately complete theory of time. Aristotle believed that time does not have a form. In fact, time is real and does not exist independently. Since he says time cannot be defined by time, and without change it could not exist. Now, how is time continuity based on the model of time of Aristoteles maintained? He believed, indeed, that time was boundless, and that it was continuous, like all great things. His fragments follow one another and touch each other. For Aristotle also, time was infinite and constant, and it cannot have a beginning or an end because of these characteristics. Actually, from unclear and defective notions of his predecessors, Aristotle formed the near-to-exhaustive and applicable time theory. His theory on time was so persuasive and useful, that for almost 20 centuries it remained a flourishing belief in science. His thoughts were like God's words until the end of the 17th century, when the notion of absolute time progressed.

After centuries dominance of Aristotle's notion of time, a remarkable thinker—Isaac Newton— dared to begin questioning Aristotle's thoughts about time. He concluded that time is absolute. His famous proclamation that "absolute, true, and mathematical time, of itself and from its own nature, flows equably without relation to anything external" gave an indication to the question of time (1687). From his view, time is a constant concept which the passage of it is uniform everywhere and for everyone. 'Absolute time' is the measure of time that is experienced by an observer in their own reference frame. It can be mathematically determined, as an observer will always only see one time for itself. From many philosophers' and physicists' perspective, it is something that seems to not exist. It seems to me "absolute time" was just the replacement for the "celestial movement" in ancient Aristotle.

Moreover, it was important for him, as Newton had "absolute time" to survive in his mechanical system. Later on, Gottfried Wilhelm Leibniz, in his book *Metaphysical Foundations of Mathematics (1687)*, after demolishing Newton's notion of absolute time, tries to describe time as all the modern physicists do. For him, time is completely denatured— it is a relative concept which has no effect on nature. His endeavor to explain time seems hard to grasp, indeed. He takes time as simply a relation whose extent is called duration, a relation that conceptualizes from the nature of change. He argues that:

"Time is the order of existence of those things that are not simultaneous. Thus, it is the universal order of changes, when the specific kind of change is not taken into account."

Years after, another idea about time was developed by a philosopher who called himself the Copernicus in philosophy. Given Immanuel Kant's reputation for establishing difficult, not to say obscure, philosophical views, even a casual reader of Kant's magnum opus *Critique of Pure Reason (1781)* realizes the prominence he gives to discussion of time. It is worth mentioning that the discussion between the Leibnizians and the Newtonians concerning the status of space and time formulated part of the fundamental background to Kant's opinions on time throughout his career. Kant does clearly mention to this theoretical that space and time are transcendentally ideal, that is they are mere "forms" of intuition, that they alter upon the "subjective constitution of the mind,". Simply stated, Kant himself is constantly saying that "time cannot be perceived": events do not come to us with their dates stamped on them. Kant puts it in this way:

"Time is nothing else than the form of the internal sense, that is, of the intuitions of self of our internal state."

While thinkers who inspired by Newton conceived time as a constant entity, it was physicist Albert Einstein centuries later by borrowing Leibnizian "relationalist" view and negating Newtonian "absolute" conception showed that time is an illusion; it is relative— it can vary for different observers dependent on your speed through space. To Einstein, time is the "fourth dimension." Space is designated as a three-dimensional arena, which provides a traveler with coordinates— such as length, width and height—showing location. Time provides another coordinate—direction—although orthodoxly, it only moves forward. Moreover, if Einstein's special theory of relativity is factual, then whatever is situated in time is located in space and vice versa. In the words of Einstein (1921), "It was formerly believed that if all material things (matter and energy) disappeared out of the Universe, time and space would be left. According to the relativity theory, however, time and space would disappear together with the things."

As a side remark (it is very important for the readers to know), I should add here that, typically, physicists are not preoccupied with the nature of time, but rather with the time of nature. It means that physical time has various types and appears in different theories of physics which have been mostly founded on a metaphysical conception rather experimental observation. For example, these theories of time are expressed in the frameworks of classical mechanics such as time in relativity theory, time in thermodynamics, time in quantum field theory, time in cosmological speculations, and the like. While they are useful shorthand for our everyday lives, in themselves they are nothing but theoretical principles. To put it more precisely, since physicists are not interested in the *Being* and its relation to time, their efforts concentrate merely on *the measurement of time*.

So, for instance, it is often said that Einstein's *Special Theory of Relativity* is a theory of measurement— a reflection on the measurement of time. However, I found out in his 1905 paper *"On the Electrodynamics of Moving Bodies*" and also his book *Relativity*: *The Special and the General Theory (1916)* that although he begins with a reflection on the measurement of time in these mentioned works, he closes with mind-boggling new thoughts of the nature of time. Nevertheless, solving the problem of "simultaneity" always became problematic for him.

In later years, Einstein tried to expel simultaneity from space and reached a compromise that simultaneity is a deep-seated feature of time as it relates to space.

Einstein regarded that time is permanently relative to the observer. He indicated that time is not always linear and not the immovable customary that we had come to admit. But, the modern physics showed us that events cannot always be profoundly ordered in time. We may need to fundamentally reanalyze our concept of time itself. In line of this argument, George Berkeley in his *"Treatise Concerning the Principles of Human Knowledge" (1710)* argues that "Esse est percipi" ["To be is to be perceived"]. He challenged that people could merely directly know sensations and ideas of objects, not abstractions such as "matter". His statement "To be is to be perceived" means indeed "to be is to be observed". He believed that not only is physics evidently a construction of observers, but also the world itself is dependent on the perceptions and interfaces of the observers. Thus, investigation of space and time plus spatial and temporal observer perspectives is necessary. Suppose that time and space are neither subjective nor objective ideas, but products of the interaction between the world and the observer. How could we analyze the time? As a short answer, I should mention that we will be enabled to analyze in a new way the concepts of time, and its sequence.

Undoubtedly, Einstein's theory of relativity, Planck's quantum mechanics, Bohm's quantum theory, and Rössler's endophysics are the exceptional influences of the 20th century on the science of time. What they share is a new notion of the observer's position. These physical theories of the world have led us to believe that the existence of the world is supported by observation. Without an observer, we cannot verify the existence of the world. The observer-dependency of the world was the last nail in the coffin of the classical dichotomy of subjectivity and objectivity, even in physics; let alone Kant's question as to whether time and space are subjective modes of perception.

It is worth noting that Einstein's relativity on time also opened new discussions in other fields from philosophy, psychology up to neuroscience. It brought lots of questions into understanding the concept of time in modern era. As I close this section in historical journey on time, I should mention that grasping time is not restricted to hard core sciences or philosophy. Time not only is a challenge in abstract thinking, but also it brings lots of glitches in practical life. In music, for instance, the concept of time is a crucial topic. As a matter of fact, musical time is a special case of time in general. As David Epstein in his book, *Shaping Time: Music, the Brain, and Performance (1995),* explains how it is difficult for a musician to grasp tempo in music:

"Motion, as process- more precisely, the pacing of motion, and the control of that pacing- is served by tempo. Controlled pacing, however, implies structure. Thus, tempo is not an ad hoc aspect of music, found or determined by chance or whim. To the contrary, it is shaped and built by its own intrinsic means- it is indeed structured. Failure to realize this may be one of the major causes of tempo confusion, of unsatisfactory choice of tempo."

2.3. Models of Time

Time is the answer to hope for the present.

—Emanuel Levinas

When one ponders about the time, inevitably the "flow" of time comes on top. The matter, passage or apparent passing of time is important and difficult. In fact, how does the world grow in a 4-dminsional/3-dimensional+time situation (in the Einsteinian sense)? This is a fundamental question which has occupied the great minds in physics and philosophy for centuries. For instance, some believe that the flow of time is made by the existence of events themselves. In fact, events do not fit into a pre-established time system, like logs following the flow of a river. There exists no flow of the river separate from flow in the river— nothing extra. P. J. Zwart, in his seminal article (1972), *The flow of Time,* states his idea as follows:

"Events do not just have their places in time like pieces of wood floating in a river, but events constitute time…the flow of time is nothing but the flow of events. Therefore, we should not compare events in the flow of time with objects floating in a river, but with the molecules of water the river is composed of. As the passing of molecules of water constitutes the flowing river, so the passing of events i.e. their occurrence, constitutes the flow of time."

However, the majority of scientists and philosophers do not agree upon this concept that time flow or temporal passage is a property of the physical world. Eddington (1920) puts this scientific notion in an eloquent and poetic way:

"Events do not happen; they are just there, and we come across them. 'The formality of taking place' is merely an indication that the observer has on his voyage of exploration passed into the absolute future of the event in question."

In fact, the discussions about the flow of time and its forms have been expanded in breadth and width in many texts. To the best of my knowledge, all these debates can be summarized into these models in mainstreams which have been proposed: *dynamic and static*, *linear and circular*, *the A-series and the B-Series*, *discrete and continuous*. Here, I try to give a short description on these models of time.

In dynamic view, one may call this the "accretional" interpretation of the world and time. This model proposes that the future does not exist and the world grows by the constant accumulation of new objects and events. Simply stated, time in a dynamic world is by definition a world where actual situation becomes different from time to time. Once they are added, accordingly, these objects and events are present, but afterward they shape part of the past. Charlie Dunbar Broad (1959) one of the scholars on the concept of time writes of "the continual supersession of what was the latest phase by a new phase, which will in turn be superseded by a new phase," and mentions to this quality as "the rock-bottom peculiarity of time" (1959). In other words, he implies that the past and the present are real, the future is not. On the other side, Storrs McCall, in his book *A Model of the Universe (1994)* sees time as a completely different from how Broad sees. McCall hypothesizes that the world, not only is

growing by the accretion of new facts, but also it shrinks, so to speak, by the removal of facts. He adds that the future and the present are real, the past is not.

As I mentioned earlier, according to the dynamic model, the world grows over time by the accretion of new facts or states of affairs. In this model of time, the moment at which occurrences are gathered in space-time to shape a continuous flow is the world-wide moment simultaneous with "now." Depending on which physical theories one chooses, the points belonging to this moment can be absolutely simultaneous *(Newtonian physics)* or relatively simultaneous *(Einsteinian physics).* There is also a hot debate whether the laws of nature in the dynamic world view are deterministic or indeterministic. There are a number of philosophers, like Hans Reichenbach, who believes that in an indeterminism is both a necessary and a sufficient condition for the world to be dynamic (1927). On the contrary, Michael Tooley, in his book, *Time, Tense, and Causation (1997)*, discusses against both the necessity and the sufficiency of indeterminism for a dynamic world. He maintains that the sufficiency of indeterminism is the best fit for a static world. Further, the protagonist of the dynamic view of time argue according to the relationship between language and time. They take tenses in language use as an index in proving dynamicity of time. This view claims that everyone who uses tensed sentences in a language, and understands them in the usual way, is conveying the belief that the world is dynamic.

On the other side, there exists the camp of the static model of time. The static model which was first proposed by Thomas Digges in 16th century claims that there is no such a thing as expansion— the world is infinite and static, it is not expanded and not curved. In other words, both space-limited and time-limited is the universe and space neither expands nor contracts. The so called spatial curvature in this universe does not exist: it is 'flat' or Euclidean. There was a heated debate on this subject until Einstein's thesis expanded universes concluded the debate.

Aside from considering time as a dynamic or static concept, there is another classification that splits the idea of time into two groups: (i) the linear and (ii) the circular. In the linear idea of time these series stretch to both directions open-endedly. In this view of time, there is an initial (creation) and a terminal point (eschatology) and an initial and an endpoint. Within the circular notion, when extended to one direction, the sequence of times will return to the other direction in some way. These people beloved in circular time: Pythagoras, Empedocles, Heraclitus, Plato, and several others. Plato speaks of reincarnation, for instance. In a very modern age, Gödel also felt, as a mathematician, that time was not what it looked like; it was circulatory. He says that our commonly understood linear distinctions between past, present and future go away and our experiential outlines are endlessly repetitive. Adherence to a circular definition of time, however, raises problems because we have an effective linear causality, and thus linear time in our world description and understanding.

As a side remark, however, most people's cultures are stuck with linear time models at great expense for the psyche. It becomes a precious commodity when time is considered linear. That's why we all assume it's either running out or ahead of us, which means we hurry up. This is not limited to average citizens. From the point of view of psychologists, it is the schedule that is the hardest thing to handle. Our creativity decreases with us when that happens. There is a possibility that the idea of time will make us robotic and automatic, as we now understand the time clock.

Back to the models of time, there is another model which has been promoted by philosophers of time in mid-20th century. It considers time as a model which roots in events. This idea began by a claim of the ancient Greek philosopher, Parmenides. In fact, Parmenides' assertion that *"the real is not real; or that which is is that which is not"* inaugurated a

philosophical institution in modelling time among some philosophers like McTaggart. McTaggart's disproof of the reality of time (1908), has provided the conceptual frame for many thinkers. McTaggart's argument is focused on the nature of events. For him, the temporal points of events *prima facie* come under two explanations: (i) the event is previous than one set of events and following than another set. So, these events are categorized in a tenseless which he calls them "the B-series". For instance, once I say that the World War I is earlier than the World War II, I signify to these events as category of the B-series. (ii) the event has a temporal point in relation to the present. The event is present or past or future. So, these events are "the A-series". For example, when I say World War I is present, or that both World War I and World War II are past, I refer to them as members of the A-series. So, McTaggart's premise is orbiting around this idea that change is essential to time to be considered real and based on this classification B-series events are unreal. Now, which series of events, A-series or B-series have this feature? McTaggart's response is because no change is situated in the B-series, so the relations containing it never change: if the First World War is ever earlier that the Second World War it is always earlier than it. The B-series' order is like the order of the letters of the alphabet which they do not experience change. So, "the B-series by itself is not sufficient for time, since time involves change".

Whether time is discrete or continuous is still an open question. The camp of discrete model argues that time flows in a detached, discontinuous and gappy form and the other side believe that it is interconnected and there is no fissure between. Like many of our modern questions which roots in ancient Greek, so this question. For instance, Aristotle believed that time has greatness and, like all great things, it is continuous. His fragments are in sequence and interact.

Furthermore, the flow of time was endless and continuous for Aristotle and cannot have a beginning or an end as a result of these features. Moreover, the classical scientific world view represented by Laplace´s demon shows as the belief in continuity of time: if a demon realized the positions and velocities of all particles of the universe at some point in time, he could reckon every state of the universe at any time! From this viewpoint, time is a purely continuous feature. In other words, there should be an accurate level of explanation that constructs the passage of time a kind of change that neither brings anything new nor loses anything.

The hunger for understanding continuous or discrete form of time can be seen even in the fields which they do not have close connection to time. The Heraclitan sense of ceaseless change appears to mean that no concept of time continuity. The Hegelian law of dialectic growth, and the Bergsonian ever-changing elan vital proves this part. Bedsides, the Darwinian natural selection law can be regarded as a shift law that provides time for a continuity definition. Although it seems that the issue has already been settled in favor of the continuous character of time by help of theories of Einstein's *Special and General Relativity*, for some it is not and we should be suspending judgement (Forrest, 1995). Forrest tries to prove the discrete form by helping the quantum theory. There are lots of debates on this topic which is not contained in the capacity of this volume.

Up to now, you have noticed we live in diverse contexts of time models which are differently separated and superposed on one another. In this situation, giving a precise definition of time seems cumbersome. Besides, by diving deeper in the concept of time we grasp this fact that by different models of time whether it is continuous or discrete, whether it is linear or circular, etc., each kind has its own practice and right in its universe to exist.

As I am closing my last paragraphs in the time segment (no-one can close discussions on the time concept), I would like to say at the end of this section that I am wondering how

spectacular a human creature is. Of all his abundant abilities, his ability to produce an abstract idea of something he still does not understand is his most beguiling ability. Of course, time is the case. Should we assume it is just the preference of *Nature*? Or is there no time and we actually use it to support our everyday lives or scientific works as a shorthand abstraction (SHA)? Or, is it an intellectual edifice only? Really, I don't know! However, as our intuitive sense undeniably tells us that time is something with which we live, something far more vivid than the short-sighted abstraction of a mathematical entity, to which physicists refer in their theory or philosophers argue in metaphysical terms with their discourse, we should see time as a real entity which is common in all of our activities. In particular, our intuition cries out to transmit us that time is something that flows in comparison with the frozen physical time. It is logical to accept it as a denominator in our lives until we feel we are moving in time.

3

TIME AND BEING: PHENOMENOLOGY OF TIME

Ja! ich weiss woher ich stamme!
Ungesättigt gleich der Flamme
Glühe und verzeh'r ich mich.
Licht wird alles, was ich fasse,
Kohle alles, was ich lasse:
Flamme bin ich sicherlich!

—Fredrich Nietzsche

3.1. Phenomenology of Time

Before entering to the complexities of phenomenology of time, let me clarify what phenomenology itself is. Phenomenology is the analysis of human experience from first person perspective. It studies the ways things present themselves to us in and through such experience (Sokolowski 2000; Gallagher, 2012). Phenomenology is considered a systemic effort to explain the basic structures of conscious experience, such as temporality, spatiality and purpose. It is focused not on the contents of experience but on the form and structure. In the 19th century the German philosopher, Edmund Husserl, regarded the precursor of the movement as phenomenological. It is worth noting, however, that his own interpretations on the structure of consciousness are never certainly clarified by Husserl, and this is without doubt one of the reasons why his multiple, volume-laden works on the subject are not clearly synthesized and often incomprehensible.

Phenomenology also raises a critical question: is phenomenology mainly a philosophical system or is it a quality research medium in the human sciences? If it is factual that phenomenology investigates consciousness in general and not consciousness as mine or yours or anyone's in particular, could we say that it is still a scientific approach? In adopting Husserlian's stance it suggests that phenomenology provides both an ontological framework which addresses the key philosophical interests and an extremely useful method of empirical study.

Phenomenology, to put it simply, is both a philosophy and a method. However, in one thought process, it is not always easy to separate these two phenomenological forms and functions from each other. Some psychologists, for instance, have tried phenomenological methods to explain human mental disorders and to create a psychiatric structure (Borgna, 1981; Van den Berg ,1982; Kimura 1982; Corin, 1990; Davidson, 1994; Fuchs; 2005, Sass, 2010). Whether these phenomenological methods have an impact on our current understanding of human mental problems and whether this represents a promising system after all are open questions which I leave them to the course of time to be answered.

The phenomenology of time began with accepting this notion that objective time does not exist— time does not inhere in nature. In other words, from a phenomenologist's viewpoint, there is no such a thing as world time and his purpose is to describe the appearing time as appearing. The specificity of the human time experience is mostly considered. Phenomenologists investigate time as a linear succession and simultaneity of abstract 'new' ones, mainly about when anything happens, how long a particular state of affairs may last and what happens earlier or later.

There are some tempting questions that are posed over and over again in phenomenological discussions: Is phenomenological time real? Will we understand the essence of time by analyzing it subjectively? Maybe not work for some. Some scientists claim that the only simple physics 'can tell us what real time is' and that the physical sense of time needs to be replaced by the witness of time-experience.

Obviously, phenomenologists in the past and in the future (as does Augustine) do not provide a metaphysical hypothesis on the relation between time and motion or transcendental and cognitive hypothesis about time in terms of a mental dependence (as is Kant). They examine instead the fundamental consciousness structures that make the unified perception of an object possible at continuous moments. The heirs of the Husserlian phenomenological conception of time in future are Martin Heidegger, Jean-Paul Sartre, Maurice Merleau-Ponty, Hans George Gadamer and Jacques Derrida. For example, Heidegger sees natural things, not in themselves, as temporal, as being part of our (Dasein's) world, as a phenomenological perspective for these thinkers. Heidegger sees them as temporal. Also, Jean Paul Sartre, in his book, *Being and Nothingness (1943)*, brings a bunch of reasons to convince us that time is not a natural compartment of nature.

Although it seems that these scholars are the pioneer of phenomenological study of time, we can find the trace of this movement in Buddhism centuries before. According to Buddhism, the past is not real, because it no longer exists, and the future is not real because it has not yet come into existence. We have only the present moment which is a real existence. Also, they believe that any effort at analysis of the very moment in which we exist is futile.

In the discussions of time phenomenology, there is a doctrine about time and being which sees the concept both scientific and metaphysical. That is, it conceives time as radically opposed to quantity and as the basic stuff of a universe that is ultimately spiritual. This idea proposed by Bergson in his essay *Time and Free Will (1889)* considers temporal entities metaphysical as well as scientific. However, it should be noted that Bergson's scientific view

of time (his objection against quantitative time) implies an *instrumentalist* view of scientific theories— they are as devices for facilitating predictions or giving a convenient basis for mathematical reasoning not claims that could be true in some sense. For him, time certainly inheres in nature, though not as a quantity. Bergson believed that time-change *(durée)* or the flow of consciousness in time is something exclusively immaterial. He maintains that:

"a flowing or of a passage, but of a flowing and of a passage which are sufficient in themselves, the flowing not implying a thing which flows and the passage not presupposing any states through which one passes: the thing and the state are simply snapshots artificially taken of the transition."

Although Bergson assumed that time-change *(durée)* is completely an immaterial procedure, he considered time as a concrete concept. It seems to me there is a conflict with the theme of the concreteness of time and abstractness of time-change in his theory. Have we found Bergson's contradiction with himself? Perhaps not. In fact, Bergson belongs to the small band of philosophers who decline to isolate the content of time from its form.

It looks like that Bergsonian emphasis on temporality paved the road for advent of the subsequent Heideggerian phenomenology. Heidegger as a legacy of phenomenology gives the most sophisticated explanation of human temporality in his book *Being and Time (1927).* By combining Kierkegaard's study of eternity in time and Husserl's phenomenology of internal time-consciousness, he formed his thought. It should be noted that he did not just merged these ideas eclectically, but he added his own interpretation of a primordial temporality. Interestingly, from Heidegger's opinion, both Kierkegaard's and Husserl's concepts of time are impure, inadequate, and incomplete because neither vision relates human being to temporality attentively enough: Kierkegaard is incapable to illustrate why the self essentially conceives itself as temporal; Husserl incapable to illustrate why consciousness unavoidably constitutes itself in time. Then, Heidegger continues his arguments with this inquiry: is time the skeleton of human existence? For Heidegger, it is so.

Heidegger's idea of time seems open a possibility for understanding of consciousness. For him, it is the being as a whole that has to be studied from the point of view of time. It is the attempts to uncover entities in their being by the particular understanding of time, by the particular level of theoretical explanation of the phenomenon of time. His own existentialist investigation of *Dasein* (human existence) or better to say his phenomenologist's approach begins with instantaneous human experience itself, and time considered as being derivative from this experience: *Es gibt Sein, Es gibt Zeit.* In his words, it is perceived that the *self* is intricately bound to time. They are interconnected in such a way that it seems neither can exist without the other. Time is recorded through the self, but the self cannot grow without the experience of time. Furthermore, he tries to show that human beings' misinterpretation of temporality is the basis of the mistaken belief in the nature of physical time.

Heidegger goes even farther and concludes that there is no such a thing as natural time. He proves his statement by this argument that because *now* possess a property of "referential significance" (*Bedeutsamkeit*), consequently, it also has the character of *in-order-to*. In other words, because 'Now it is time to…' is followed by a verb in our daily conversations, a referential significance is reflected in it. In result, we have a 'world-time' which is far away from the natural time. The upshot of Heideggerian thoughts can be said as follows: the original present is ubiquitous throughout time, that is, it grounds a now as a *Übergehen* that is no part of time. So, by this mechanism, *now* is not that part of time which was future and will become past. The original present always-already possesses a future which does not become present. And the original past is a past which was not a previous present.

Later on, we also encounter to some ideas about time and being in 20th century phenomenologists who have been influenced by Heidegger and his works. Emmanuel Levinas is one of them. For Levinas, the *self* is significant in a strong and candid sense. He maintains in his book (1987) *Le Temps et l'Autre (Time and the other additional essays)* that consciousness does not need things in order to exist, in the way things need consciousness. However, the crucial contemplation here is that this self which exists before the world, does not exist outside time. Its essence is temporal. Accordingly, it is Levinas's task to unveil the mystery of this out-of-time self, to tell us how we are to comprehend consciousness without locating it in the space of time.

Levinas thought that the instant has no duration and in its interaction with being reveals its detachment from being. He believes that the fundamental thought which allows us denying the instant has to do with the fact that, by itself, the instant has no magnitude, no duration. However, we may not understand Levinas unless we grasp the special meaning of 'central instant'. Suppose I say that an event happened ten instants ago. Since 'ago' is a tensed word, I have situated the event in a tensed time series which have a central instant, i.e. the instant we call 'now'. Also, I could have situated the event in the tenseless series— the B-series (I explained the A-series and the B-series in the previous chapter). In this circumstance, its time-position becomes permanent without reference to a central instant. Nevertheless, in locating it in the tensed series, let's link it to what is ordinarily understood by 'the central instant'. From Levinas's view, the concept of central instant *(Now)* fails to qualify as central. From an intuitive perspective, now is a favored concept and it shapes our perspective on the past and future. It is also a member of the series, it comes after some *nows* and before others. But, for Levinas present is central in that it is an absolute initiation that cannot be put into relation with other serial instants by means of the notion of 'ago.' Levinas's present is not just a beginning, but a beginning that "comes from itself". His present is a power-base rather than a perspective. It is completely windowless. Put it in much simpler words, he insists to convey that present is everything, because we are it, and it is also nothing, because we do not own it. We have no present, it slips through our fingers.

In much more modern time, there are also some notions which support the phenomenological perspective on time and being. For instance, Hameroff (2003) believed that consciousness creates time and so does events. Whether these events are those that encompass passage or it is an experiential phenomenon of duration for fixed and stable objects, it depends on unavoidable events such as breathing and body movement. Likewise, events not only impact on perceiving time, they are necessary to the phenomenon of duration judgment.

On the other side, for some non-reductive philosophers, the nature of time cannot be studied through a phenomenological way. In the style of the integrated image proposed by Thomas Nagel in his 2012 book *Mind and Cosmos: Why the Materialist Neo-Darwinian Conception of Nature is Almost Certainly False* (following Wilfred Sellars), subjectivity of the time is a non-reductive concept as part of the real world. For Nagel, our world would be neither wholly physical nor wholly mental, so be our subjective time world. He believes that we should attempt to go beyond the difference between appearance and reality by including the existence of appearances in a developed reality. So, nothing will then be left outside. Besides, Nagel admits scientific realism (the view that the theories of science can be true). However, he rejects the *'replacement thesis'*—the claim that first-person experiential statements can be true only if they were construed into the vocabulary of physics.

3.2. A Reflection on Time and Our Existence

Es gibt Sein. Es gibt Zeit.

—Martin Heidegger

By looking closely at our instincts, we understand that ordinary experiences arise in time and time tends to be a function of the world — we believe that time exists. This apparently simple fact that how time and our conscious experience are related to each other is one of the most challenging issues in many disciplines like psychology, neuroscience, and philosophy. How do we perceive time? How is it possible that despite some type of separation of temporal parts, human consciousness unifies it into one experience in order to give us an awareness of anything that happens in time? Does time exist on its own or projected onto things by consciousness? In other words, do time and the temporal features exist independently of conscious experience or their only being is in and for consciousness?

In my opinion, the relationship of time and consciousness is a very antique concept. I suppose that it originates from grasping the concept of death. Man has been portrayed by himself as mortal since ancient times. It is only because human mortality, which is common to all living things, is a problem that human beings are a special being that knows their own deaths, i.e. the temporal limits of their own lives. For some "time is an essential element of the universe," they mean perhaps not only that time, but also that it exists as autonomous from man, is an essential element of the physical reality of this universe. However, since men are part of the world at last, the consciousness can't be isolated. We are closely linked to time. Our perception and consciousness of the universe are very dependent on it.

The close intertwined essence of time and being can also be traced in literature— past is used to give sense to the present. The young Hal, in Shakespeare's second series of history plays, must realize the value of time; to understand time for him means to come into a complete ownership of his historical identity. We can also comprehend the importance of time in works of Thomas Mann such as *Der Zauberberg (The magic Mountain).* Familial continuity, for Mann as it did for the bourgeois society of the nineteenth century, obviously specified the flesh-and-blood sense of historical value. Furthermore, in Proust's *À la recherche du temps perdu (In Search of Lost Time),* exhibits the thickness of time and its relation to the living present. In his novels the structures of time what he offers is similar to the ones Husserl recognized it to have ("retention" and "protention" which I will explain in chapter 6). In one of the scenes, for example, Proust shows the depth of the past narration. We can see, from the opening sentence on, to be "retentively" held in instantaneous presence throughout the happenings occurring from the moment the narrator enters the library of the prince, including, the moment he sees *Mile de St. Loup*. In a similar way, all the plans concerning the writing of the novel expressed in the uncertain present, can be seen as "protentions" presently held by the narrator as he recalls and as he meets with the same surprise the guests of the *matinee*, now transformed by age, and *Mile de St. Loup*. There are more examples of this sort. World literature is full of these stories about the importance of time and our existence. Why is it so? Why is time so important for us in shaping our identity and also continuity of our *self*?

Likewise, time is not something that relates merely to the individual consciousness— an only subjective issue. We have also social time which bounded us from the beginning of life. The term "social time", denotes to the experience of inter-subjective time shaped through social contacts on the behavioral level—a time experience which is shared by people living under similar social settings. In accord with the communal nature of a society, different cultures develop specific, adaptable forms of social time. For example, in the study of different time prospects and time orientations, different groups within a society shown diverse thoughts about time: the poor have less time; they incline to live in the present, while industrialized societies lean to be future-oriented; non-industrialized ones are past-oriented. In another experiment, LeShan (1952) states that the middle-class children in America who have been requested to invent stories tell stories that have a longer period than those invented by working class children. Also, comparative studies in different societies on the value of time have brought evidence that shows that in economically less industrialized countries time is not being seen the same value as in highly industrialized countries. Societies are the keeper of time, and it appears that time is bound up with a society and life of individuals. There is no question that societies are the determinant of time's being valuable or valueless for an individual.

In Myth of the Eternal Return (1989), anthropologist Mircea Eliade maintains that by invention of clock time, the perspective of human toward time *per se* changed dramatically. He believes that by the invention of the clock societies advanced in a mode helping people to coordinate more efficiently. It was also giving a means by simultaneity to align activities, communications and meetings in distant sites. A higher level of organization among people was achieved. Most of events ensued more by social needs than by conditions of weather or nature. With the invention of writing, consequently recording history was born. They were able to track each moment of history and collective awareness obtained a trajectory from past to present and into the future. With increased appreciation of the uniqueness of each moment, new chances for individualism centered on the uniqueness of each self-moving through time.

Consequently, the invention of clock brought temporal problems of our lifetime. Sometimes adjustment the subjective time (internal time) to an arbitrary or clock time brings lots of behavioral problems for the children. For instance, according to a study done in the USA, fifty percent of the children referred to child's behavior problem clinics have been enforced at earlier ages to conform to painstaking schedules. One factor in their behavior problems may have been that these children needed more time to be adjusted the basic rules of socialization. It seems that many of our psychological problems come from the maladjustment of subjective and objective time which have not been well studied yet. Nevertheless, this study not only gives us a firm confirmation of the intricate relation between our life and time, it also draws our attention to the importance of time in shaping our behavior and actions. Personally speaking, it's sad for me that we lose control of lives out of efforts to control our lives during the coordination of our clock, now so dominated by the clock that we have lost touch with natural beats that are present at the moment.

By pondering about the relationship between time and our existence, we may doubt whether there is such a thing as time which plays a pivotal role in our life. We may say that time seems to be an illusion. But by a meticulous look at it, we realize that although we do not perceive time as a concrete concept which relates directly to our existence, the "now" is evidently present in our lives. It is part of our existence and it is our instantaneous gift of living. That is why in English "present" has two meanings: *now* and *gift*. It is such a precious gift that our sense of nowness strengthens our entire conscious experience. From one side,

experiencing the present as a distinct entity allows our brain to trail the passage of time, and from another enables us to intermingle with the world. There exist a school of thought (mysticism) that considers the *now* as an exemplification of eternity— it is the place of life. It is the bedrock of the early experience of “going-on-being”.

4

BRAIN TIME: TIME IN NEUROSCIENCE AND PSYCHOLOGY

"Look at this gateway! Dwarf!" I continued talking: "it [the gateway] has two faces. Here two roads come together: these no one has yet gone on to the end. This long lane backwards: that takes one eternity. And that long lane forward— that is another eternity. They contradict each other, these lanes; they hit each other at their foreheads: and it is here, at this gateway where they abut upon each other. The name of the gateway is inscribed above: "Moment."

—Fredrich Nietzsche

4.1. An Overview on Brain and Time Studies: From Phrenology up to Modern Neuroscience

Time has been always a perplexing question in different fields: philosophers contemplate what time is, and whether it is a single moment or a full-scale element. Physicists tackle with this concept why time acts as if flows in only one direction, or whether time travel is feasible, and even whether time exists at all. Neuroscientists and psychologists, in turn, come to grip what it is like to "feel" the passage of time, how the brain expresses time, and why humans are uniquely gifted of mentally projecting ourselves into the future. And time is

at the heart of the most challenging, unsolved question of free will: is the future an open path, or predetermined by the past?

The first trace of the significance of our sense of time in psychology and neuroscience refers to phrenologists in 18th century. Phrenologists (or cranioscopists) measured the bumps on the skull to predict mental traits and individual's psychological attributes. It was established by German physician Franz Joseph Gall in 1796. It became an influential movement in understanding brain and its relation to mental traits in the 19th century. Gall advocated that the brain can be divided into twenty-seven distinct "organs," which we call "regions" in today's neuroscientific jargon. Nineteen of the arbitrarily divided regions were responsible for capabilities common with other animals, such as reproduction, memory, and time. The remaining eight regions were specific to humans: the sense of metaphysics, poetry, satire, and religion. In modern time, phrenology is scorned as pseudoscience because we know that bumps on the skull have very little to do with our behavior. Apart from diverse mental faculties which they assigned in different regions of skull, they allocated our sense of time to an area of the frontal lobes. According to one phrenology text, "The office of this faculty is to mark the passage of time, duration, succession of events, etc. It also remembers dates, keeps correct time in music and dancing, and induces to punctuality in the fulfillment of engagements."

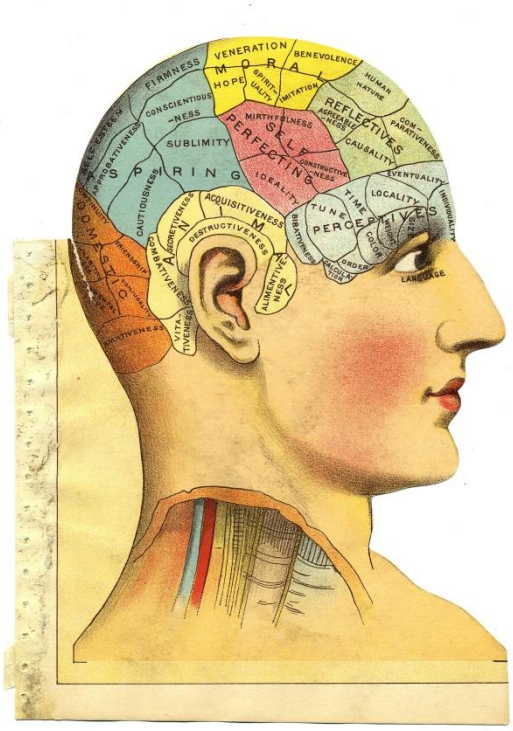


Figure 4: *A phrenology chart. The sense of time can be located in frontal part of the brain.*

William James, one of the founders of modern psychology, acknowledged the importance of time to understanding the brain. He devoted a chapter of his work, *The Principles of*

Psychology (1890), to the perception of time. Peculiarly, since then few books in psychology or neuroscience have done the same. Indeed, we see throughout most of the twentieth century, the problem of time was somewhat abandoned and largely omitted from textbooks. It seems to me the research question is a cumbersome one to be grasped easily and few bother themselves to investigate on such a peculiar concept. For example, in line of my argument, Adams in 1964 comments on some of challenges in understanding time in psychology. He writes:

"... time perception is a venerable, tired topic in psychology that interests very few active investigators any more, perhaps because no one bothered to explore the mechanisms of time perception and how [they] might enter into meaningful interaction with other mechanisms."

However, this deprivation is not limited to the past. Pick up the bible of modern neuroscience, *Kandel's Principles of Neural Science*, for instance, and look for the most common noun in the English language (*Time)* in the index—you will not find it! But, why such an important concept like time have been overlooked? Perhaps, I am oversimplifying a bit, but I suppose that the answer lies in the fact that psychology and neuroscience are fledgling scientific subjects— they are only beginning to fully come to grasp the significance of time. As Richard Ivry in his article *Dedicated and intrinsic models of time perception* (2008) puts it in this way:

"A generation ago, research on timing was limited, emphasizing the study of behaviors marked by temporal regularities. More recently, a renaissance has taken hold in the study of time perception, with researchers addressing a broad range of temporal phenomena. Behavioral studies have revealed a host of puzzling effects in which our perception of time is far from veridical. Neuroscientists have described how activity in single neurons varies with time and how this might relate to psychophysical judgments. Theorists have asked how the dynamics of neural networks might encode temporal patterns in a reliable manner."

Recent years have seen a considerable revitalization of interest by psychologists and neuroscientist in subjective time experience. Due to recent conceptual shifts (in my opinion, incapability of phenomenological approaches in understanding time), along with a multitude of methodological developments, there has been rising emphasis on time in neuroscience and psychology.

Furthermore, there is an increasing acknowledgement that without an understanding the relationship between brain and time, and how the brain represents time, it will not be promising to understand the human mind.

The first building stones in coming to grasp the importance of time has been taken in mid-20th century on. For instance, after years of silence (I mean after James' chapter on perception of time), Fraisse's *The Psychology of Time (1963),* a somewhat complete review of work of the last 75 years on time in psychology, undoubtedly flickered the interest. Two large books on time such as Fraser's and Fischer's *The Voices of Time (1966),* and Fischer's *Interdisciplinary Perspectives of Time (1967)* prospered the topic. Also, in much recent time, we witness the returning scientists to the concept of time and brain. For example, in the field of *chronobiology*, the study of biological rhythms, particularly sleep-wake cycles, flourished in the recent years *(2017 Nobel Prize in Physiology or Medicine jointly dedicated to Jeffrey C. Hall, Michael Rosbash and Michael W. Young for their discoveries of molecular mechanisms controlling the circadian rhythm).*

However, for some scientists like J. J. Gibson the concept of time is an abstraction— intellectual feats— and it has no use in psychology and neuroscience. He depicts this idea in his article *Events are Perceivable But Time Is Not (1975)* as followings:

"Time and space are concepts, abstracted from the percepts of events and surfaces. They are not perceived, and they are not prerequisite to perceiving. They do not give meaning to percepts and they are not imposed by the mind on the deliverances of sense. Time and space are intellectual achievements, not perceptual categories. They are useful in the study of physics but not in the study of psychology…Isaac Newton's famous assertion that "absolute, true, and mathematical time, of itself and from its own nature, flows equably without relation to anything external" was the postulate of a physicist trying to simplify his problems. It did simplify physics but that does not mean it will simplify ecology and psychology."

Setting aside Gibson's argument against the concept of time and its vitality, we notice that everywhere we look, we see the clocks: on our wrists, mobile phones, churches, and walls. But the new discoveries in psychology and neuroscience unveils this fact that we are not only encircled by clocks, we are also crammed with them—wherever we look, we can find a clock, even in very tiny organisms. The brains and bodies of humans and also other animals gauge time—some animals are able to anticipate the seasons and even an individual cell of any organism can tell the time of day. For instance, in a recent study which has been done by a group of scientists (Buhr *et al*., 2019) in University of Washington showed that a type of opsin identified as neuropsin is expressed in the hair follicles of mice can synchronize the skin's circadian clock to the light-dark cycle, autonomous of the eyes or brain.

Now that new discoveries in psychology and neuroscience have proved the interconnectedness of time and our brain, should we look at it as a denominator in our daily life or better to say, our survival? Of course, yes. In my opinion, It is true that if we didn't have a finely grasp of time and their connection to the brain, science would not get rid of it. However, we should bear in mind that it is such a widespread concept that cannot be delimited only to our existence— our brain. Likewise, it is clear that without the faculty to track elapsed time, our morning shower might continue open-endedly. Without that irritating sensation to remind us we have been driving too long, we may easily miss our exit in the highway.

But how does the brain keep time? What segment of the brain tells time? There were many forerunners who advanced our understanding of how the brain tells and perceives time, but we now know that there is no specific answer to these questions. What we know is that evolution has asserted multitude mechanisms in the brain to tell time. Besides that, timing in our activities is critical factor in achieving a successful action. Consider, for instance, playing a musical instrument, hitting a tennis ball, and many other activities. In all of these activities the brain should implement its exquisite control over timing. Some discoveries in neuroscience have provided evidence that there is a centralized clock, or pacemaker, somewhere in the brain that keeps time for the entire brain. On the other side, a new study which has been by Wang and his colleagues (2017) in MIT conveys a model that for an alternative timekeeping system that relies on the neurons are dependable for producing a definite action. Depending on the time interval essential for an action, these neurons compress or stretch out the steps they take to create the behavior at a particular time.

In the forthcoming sections, I will explain these models in detail. But, for now, let's investigate the main three challenges of our brain and time. It seems to me that time – the 4th dimension — is always a significant concept for all scientists who study any living organism.

Why is it so? To answer this perplexing question, another question arises: what on earth is not rhythmic?

4.2. Three Clocks of Our Brain

One lies here with time passing and wonders about it. Every sort of time trickling through the hourglass, 'time immemorial', and for the 'time being', and 'time out of mind'; the time of the poet, the philosopher, the pregnant woman, the calendar . . .

—Lawrence Durrell

The brain is a product of our long journey in the river of evolution. It is assumed that it has been designed for survival in a tough and constantly changing world. Thus, the stepping stone to succeed in such a harsh world is to be able to predict what will happen in the future, and when it will happen. Hence, the brain is both an anticipation machine and a machine that tells time in different aspects of our life such as maintaining a circadian rhythm, to control the precise timing of a fine body action, and for conscious awareness of time passage (subjective time). Indeed, our brain seems to enclose aspects of a "time machine". Firstly, the brain is a physical system which exists in time. It has a neurobiological nature which is endeavored to be understood by physics, biophysics, and especially neurochemical oscillators. Secondly, it can memorize the events in time and can recall them. As Michael Theunissen uses the term "time transcendence" to indicate how the brain thus contains aspects of a "time machine". Jürgen Ehlers, the German physicist also believes that time is the way how we perceive the world around us. Ehlers offers the opportunity to see how the brain may function as a "time machine" to support this.

Thus, if we accept that our brain is a time machine, we encounter to three main timing issues of this apparatus: (i) *Circadian rhythms*, (ii) *to control the timing of fine body actions (or motor timing)*, and (iii) *conscious awareness of time passage (or subjective time)*. Let me reflect on these issues and find out how the brain manages to deal with these critical matters.

(1) Circadian rhythms

Since life commenced some 3.8 billion years ago, time duration of the earth's daily rotation has decelerated to a period of around 24 hours—23 hours 56 minutes and 4 seconds to be precise. Nearly all organisms on our blue pearl use an internal biological timer to anticipate these daily fluctuations. Circadian rhythms have been evolved in nearly every living thing on earth— in bacteria, algae, fungi, plants, animals, and humans. They assist organisms to time their daily and seasonal activities. By this mechanism, every creature is able to be synchronized to the external world and predict changes in the environment. Having this clock

permits organisms to boost functioning and behavior in advance of the diverse activities of the day and night cycle. Creatures efficiently 'know' the time of day. Such internally made daily rhythms are called 'circadian rhythms' from the Latin circa (about) and dies (day).

Historically, in 1729, the French astronomer De Mairan found that leaf movements in plants continue with a 24-hour even in constant darkness. De Mairan in a manuscript which was less than 350 words, described leaf movement, came to the conclusion that it is not controlled by light and darkness. Since then, circadian rhythms and its underlying mechanism has come a long way. It took nearly two centuries after De Mairan's observation which research on biological clocks in organisms advanced into a small new discipline. Having coined the term circadian by Franz Halberg in 1959 and insightful contribution of Colin Pittendrigh in 1960's first international conference in Cold Spring Harbor in New York brought this topic on the top. It was the first time which endogenous nature of the biological clock in organisms was born.

When we wake up without the help of the sound of an annoying alarm, we conform ourselves to a biological clock in the brain. This circadian clock has a fundamental period of nearly 24 hours, and synchronizes to the daily light–dark cycle. Both unicellular and multicellular organisms have circadian pacemakers (*Table 1.4).* In essence, circadian rhythms give a temporal framework for cells to function appropriately— it functions like an adaptive, endogenous temporal system which ensures that the same procedures occur at the same time, day after day. In other words, circadian clocks need the right stuffs in the right place at the right time. Proteins, enzymes, fats, carbohydrates, hormones, nucleic acids, and many other combinations have to be absorbed and metabolized in a precise time window. All of these procedures have to be timed to best result by the millisecond, second, minute, day, and time of year. Without this internal temporal framing and its synchronization to the external environment any organism's biological system would be in turmoil.

Biologically, all these rhythms must be *entrained* (the procedure by which light synchronizes the organism to a 24-hour day) to the external environment *(Zeitgebers),* mainly by the arrays of light fabricated by the earth's rotation, and other rhythmic changes within the environment such as temperature, food availability, and rainfall. It should be noted that the circadian rhythms are not merely determined by an external cycle but are caused internally (one of the most noticeable qualities of circadian rhythms is their self-sustained oscillation), and then entrained so that they are harmonized to the external cycle (it is called ''free-running''). For instance, there are lots of experiments (experimental isolation chamber/ bunker experiments) which show that even if we are left without time cues, our endogenous clocks still tick and endeavor to drive us. Likewise, in rodents, it has been found that the daily beginning of running-wheel movements has a standard deviation of less than 2% of the average period even in the absence of environmental timing cues (Aschoff *et al*., 1971; Pittendrigh and Daan, 1976; Welsh *et al.,* 1986; Daan and Oklejewicz, 2003).

To explain what circadian clock, free running and *Zeitgeber* means, let me convey a metaphor: Consider a child playing on a swing (figure 2.4). By stretching and contracting the legs at particular times during the oscillation, and hence systematically raising and lowering its epicenter of mass, the child can endure swinging (circadian rhythms). Practiced children can get into such oscillation by themselves without any push or outside help (free running). On the contrary, a child who has not become proficient in the specific leg movement yet is even completely dependent on regular pushing in order to help them in lasting the oscillation (*Zeitgeber)*. This is a metaphoric illustration of how circadian clock in an organism meet.

Figure 5: *Calvin gets swing! (Calvin and Hobbes, borrowed from comic strip created by cartoonist Bill Watterson, 1990)*

Seasons change and it has impact on every organism—each organism that live in the depths of the sea or in the deeps of the earth experience changes and consequently face the challenge of synchronizing their lives with the earth's rotation. In the midst of these changes, green life has to synchronize its circadian rhythms with the world outside. The circadian rhythms in plants are typically retuned by daily changes in light and temperature. For instance, in plants such as *Arabidopsis thaliana*, entraining light signals are absorbed through a sort of photoreceptors including the phytochromes, which gather far-red and red-light wavelengths, and cryptochromes, sensitive to blue light. Plants' circadian rhythms are also entrained by daily temperature rhythms but the underlying mechanism in perception of such signals is not fully comprehended (Millar, 2004; Franklin and Whitelam, 2004; Gould, *et al.,* 2006).

Neuroanatomically speaking, where is the seat of this biologically internal clock? The base of such rhythms can be documented in human fetuses starting from mid-gestation. Before birth, our circadian rhythms are induced by the mother. It seems that there are some central tissues that fulfill the criteria of circadian oscillators after birth. It is said that, in mammals, *the suprachiasmatic nucleus*— a bilateral structure of 20,000 neurons including astrocytes and multiple neuropeptidergic cells in the ventral hypothalamus— functions as the master pacemaker with circadian cells driving rhythms in behavior and physiological procedures, such as sleep-wake cycles, locomotor movements, temperature, and hormone secretion (Ralph *et al.,* 1990). This center has been located close to the chiasm of the two optic nerves. It receives light input from the eyes and multiple supporting brain regions and its output establishes stable phase interactions between peripheral circadian clocks. Lesions of the suprachiasmatic nucleus eliminate activity rhythms in mammals. Interestingly, every suprachiasmatic nucleus neuron function as an autonomous clock, using molecular feedback loops to make daily rhythms in gene expression and cellular output in the lack of external indications (Welsh *et al.*, 1995; Liu *et al.,* 1997; Herzog *et al.,* 1998; Reppert and Weaver, 2002).

Furthermore, it has been argued that the mammalian retina and olfactory bulbs play the same role (Klein *et al.,* 1991; Tosini and Menaker, 1996; Abe *et al*., 2002; Lee *et al.,* 2003). These researchers revealed that the isolated rodent retina shows a circadian rhythm in melatonin release. Nevertheless, there is not any consensus about the seat of circadian rhythms from neuroanatomical standpoint. Currently, there exist more than 100 brain regions that are potential contributors to circadian rhythm regulation. It is believed that in order to conclude whether it is a true representative of the circadian rhythm system, each of these must be individually examined (Morin, 2013). Fortunately, in recent years, massive knowledge has augmented, both in breadth and depth, about the neuroanatomical substrate of the circadian rhythms structure.

Likewise, several genes have been discovered that are at least partly involved for this distinctive activity of *the suprachiasmatic nucleus* function. The activity fluctuates on the expression of auto regulatory translation— transcription feedback loops of genes involving the *Period genes* (Per1, Per2, Per3), *the Clock gene* and two *Cryptochrome genes* (Cry 1, Cry 2). It has been confirmed in several animal studies that removal or mutation of these genes leads to abnormal rhythms or even arrhythmic phenotypes when tested under persistent conditions. Likewise, dysfunction of these clock genes might be vital in the expansion of various diseases or even cancer.

Group	Representative species	Common name	Representative circadian behaviours
Eubacteria	*Synechococcus elongatus*	Cyanobacteria	Nitrogen fixation, photosynthesis, mitosis
Ascomycota	*Neurospora crassa*	Bread mould	Formation of spores
Dinoflagellata	*Lingulodinium polyedra**	Dinoflagellate	Bioluminescence, aggregation
Chlorophyta	*Chlamydomonas reinhardtii*	Green algae	Phototaxis, mitosis, UV sensitivity
Embryophyta	*Arabidopsis thaliana*	Thale cress	Leaf movement, stem growth, photosynthesis
Nematoda	*Caenorhabditis elegans*	Round worm	Swimming, resistance to osmotic stress
Mollusca	*Bulla gouldiana*	Snail	Crawling, photosensitivity
Arthropoda	*Limulus polyphemus*	Horseshoe crab	Swimming, phototaxis
Arthropoda	*Drosophila melanogaster*	Fruitfly	Locomotion, sleep, olfactory sensitivity
Chordata	*Mus musculus*	Mouse	Running-wheel activity, sleep, feeding
Chordata	*Homo sapiens*	Human	Motor reaction time, sleep, feeding

*formerly Gonyaulax polyedra

Table 1: *Representative circadian behaviors in diverse model organisms. (Borrowed from Erik D. Herzog's article on neurons and networks in daily rhythms, Nature, 2007).*

In fact, the circadian clock is scrutinized in many diverse model organisms— from fungi to cyanobacteria, zebra fish or mice (mainly *Drosophila* or often called *fruit fly*). The first steps were taken by Seymour Benzer who recognized the first clock gene in Drosophila Konopka (Benzer, 1971). Since then, the field of chronobiology has been directing at illumination of molecular clock mechanisms.

Circadian rhythms maximize survival. They almost certainly provide a large selective advantage. Organisms that benefit circadian are assumed to have a major advantage over both their competitors and predators. However, when one mentions 'organisms', one should not think only of organisms which have brain. For example, *Gonyaulax polyedra* — the unicellular marine alga which belongs to red dinoflagellates and generally causes red tides in the Pacific Ocean— obtain an internal clock which regulates their daily functions. It seems that Gonyaulax clock functions through at least two distinct light receptors and light input pathways (Roenneberg and Deng, 1997). However, none of which has as yet been well investigated.

It has been shown that there is a close relationship between the circadian clock and human disease. There are lots of studies which indicate circadian clocks play as a factor in numerous diseases. For instance, through epidemiological findings, it has been revealed that imbalance circadian clock caused an increased incidence of cancers in long-term shift workers, higher

levels of breast cancer in Norwegian radio and telegraph operators, increased risk of colorectal and prostate cancers, and metabolic and gastrointestinal disorders (Tynes *et al.,* 1996; Schernhammer *et al.*, 2003; Sigurdardottir *et al.,* 2012). These researchers argue on the basis of the light-at-night (LAN) hypothesis. They place the hormone melatonin at the epicenter of the cancer disease process, claiming that melatonin—beyond being a hormone—is a main scavenger of reactive oxygen species. Because melatonin secretion largely occurs at night and repressed by light, oncogenesis becomes more likely while people are exposed to light at night.

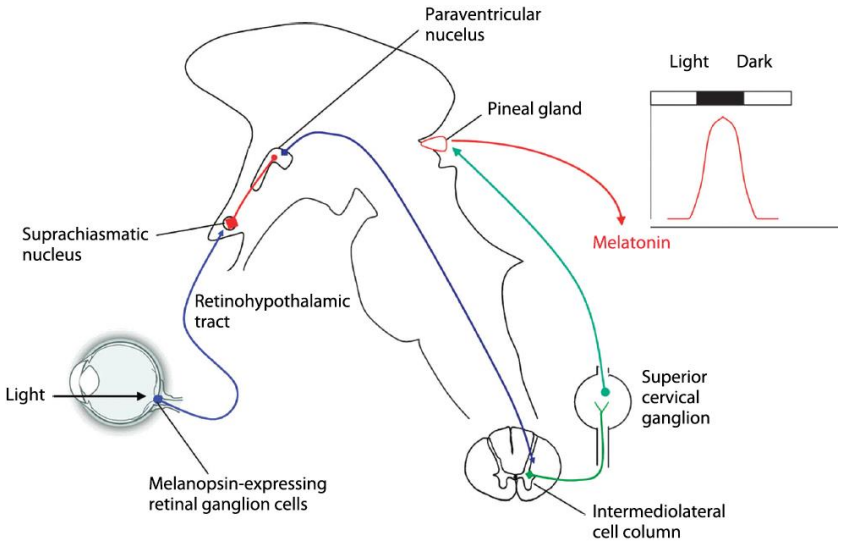


Figure 6: *Schematic illustration of circadian rhythms procedure from retina to melatonin secretion. It shows the pathway is responsible for the peak of melatonin secretion during darkness, accordingly our circadian clock synchronization. Reprinted with permission from Benarroch EE, Neurology. 2 B 2008, American Academy of Neurology*

(2) The timing of fine body actions (motor timing):

Motor control in all organisms is a be-all and end-all mechanism. As the Nobel laureates Sir Charles Sherrington comes to this conclusion that "Life's aim is an act, not a thought," and Roger Sperry, who encounter us to this fact that "to view the brain objectively for what it is, namely, a mechanism for governing motor activity." Perhaps Henri Poincaré was the first theorist who conjectured that the only way sensations turn into an experience is by linking them to the body and its movements: "To localize an object simply means to represent oneself the movements that would be necessary to reach it" (Poincaré, 1905). In any case, it is act, not thought, that pick up the piece of meal on the table or make our morning coffee.

Motor movement gains food, chews it, and digests it. Without motor movement speech, writing, hand gestures, or facial expressions were impossible to be disclosed to the external world. Action is a matter of life and death— our survival. It seems according to above-mentioned thinkers' standpoint, one of the reasons we have a brain is so that we can move. However, it seems to me that this cannot be true because even in brainless organisms such as earth worms, starfish, Jellyfish, and many others action is one of integral part of these organism's behavior.

I suppose that precise timing in action is the cornerstone of our movements. Time as an important denominator determines whether our action is done or not. I think that before entering to the complexities of motor timing in organism's acts, I should review some main locomotion theories after dawn of cognitive revolution in mid-20th century— the reafference principle (von Holst and Mittelstaedt), the corollary discharge (Roger Sperry), and TOTE model (George Miller and his colleagues).

Interestingly, to the best of my knowledge, Von Holst & Mittelstaedt's principle of reafference and Roger Sperry's corollary discharge proposed independently and almost simultaneously (both published in 1950). Having inspired by Johann Georg Steinbuch (1811) and Von Helmholtz's "Willensanstrengung" / "effort of will" concept (1896), they were the first to suggest in a thorough manner, and with experimental evidence, that motor-to-sensory feedback has a leading role in regulating animal behavior and actions (opposed to William James's *reflex theory* which supposed that all incoming messages have to proceed through a sensory channel, and the information flux within the brain have to be directed in the sensory-to-motor rather than in the motor-to-sensory direction).

These theories are three groundbreaking ones published as a profound break from behaviorism which described behavior as a set or sequence of stimulus-response actions (for instance, *reflex arc* concept which was generally accepted by scholars in that time). Moreover, it seems to me that the main incentive upon the advent of these theories was a response to the work of Sherrington and of Graham Brown on scratching and locomotion in spinal animals in the beginning of 20th century. Sherrington found that by transection of the cervical spinal cord in the dog, a scratch reflex could be obtained by mechanical stimuli (e.g. tickling the skin) within a large saddle-shaped area over the upper part of the body. In other words, he concluded that no internal feedback implementing an action is needed. These discoveries brought severe critics to Sperry's and Von Holst & Mittelstaedt's hypothesis by Charles Sherrington. He attacked this idea from every edge and concluded that it "remains unproven" (Matthews, 1982). It seems that he has not cherished the corollary discharges and afferent signals as complementary rather than exclusive mechanisms for organisms' acts. It is worth noting that this way of thinking was not restricted to Sherrington or Brown. Majority of scientists who endeavor to understand human actions mistakenly believe that the brain is sufficient to model it. They ignore the environmental variables which interact with the brain in a complex multi-factor cosmology in order to create the behavior of an organism. As a matter of fact, among these interactions we perceive the world. I suppose these three theories which were proposed compensated the lack.

The reafference principle: von Holst & Mittelstaedt first proposed this model in 1950. This model tries to answer this question that how perceptual stability of inner and outer world of an organism can be obtained in spite of the fact that the sense organs are stimulated when we move around in the world. They believe that our brain always makes a copy (they call it 'efference copy') as default picture and it always compare that copy with the outside world. The efference copy, as they believe, causes a strictly correlated neuronal process which is

stored after a certain temporal delay, into the neighboring ganglia. The efferent stream of impulses flowing out into the periphery sets its effector in motion, and this gives rise to the afference. This, in turn, interacts with the efference copy. There is a close relation between CNS and the environment. They did lots of experiment on animals for proving their notion. So, according to the principle of reafference, there exists the optimal internal "model" which represents the actual state of sensory data. In the case of goal-directedness, the brain establishes an internal model and the sensomotor-system has to play a kind of game to adjust the external data until the fitting between the established internal model and the sensory data. When this model is optimized, i.e. until the difference between internal model and sensory data is minimized and goal is reached, the brain continues adjustment process.

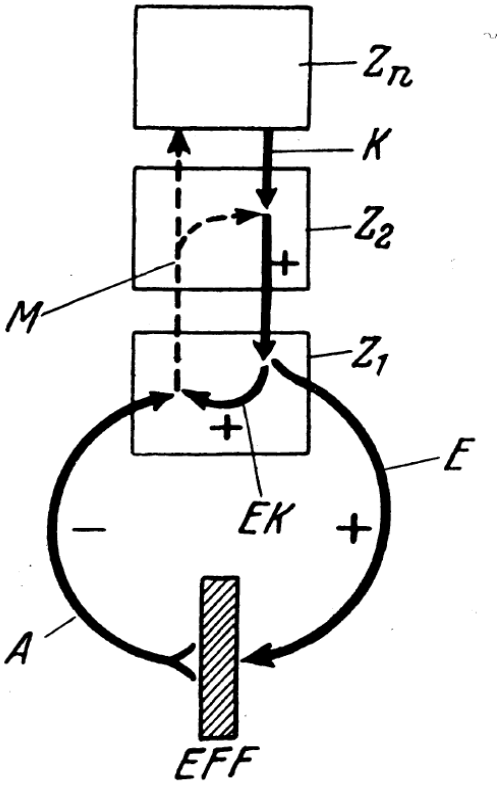


Figure 7: *General schema for the principle of reafference*

From a higher center Zn a command K is sent to a lower center (Z2); from there a neuronal command is given to an executive center (Z1), which in turn innervates (by an efference E) an effector (EFF). Simultaneously, a copy of the efferent command E is stored [efference copy (EK)]. After the movement, an afferent signal A (or the ''reafference'') is sent to Z1, where this reafferent signal is compared with the EK. If A (with a minus sign) resembles to EK (with a plus sign), both signals cancel each other, and the sensorimotor cycle is completed. If EK and A do not match, a message (M) is sent to Z2 and Zn to correct or to re-initiate the sensorimotor cycle until it ultimately comes to an end.

From von Holst and Mittelstaedt's viewpoint, each organism's CNS behaves in an automatic scheme— either directly or indirectly— with the surrounding environment in the world. For these authors, there is a lawful relationship which should be discovered. In the beginning of their notorious article— *The Principle of Reafference: Interactions Between the Central*

Nervous System and the Peripheral Organs— while introducing the principle of reafference they try to draw our attention to the importance of this concept:

"A major question for the physiology of the central nervous system (CNS) has always been this: what lawful relationships hold between impulses which are generated by external stimulation and travel inward into the CNS and those which-either directly or indirectly-reemerge from it; that is, the question of the relations between afference and efference? The CNS has been characterized as a sort of automat, which reflex delivers a given ticket when a particular coin is inserted in it. For simple protective reflexes-like sneezing and withdrawal from painful stimuli-this idea is easy to accept; for more complicated reactions such as balancing and orienting responses, the same conceptual scheme has been advocated. Even rhythmic 1ocomotor patterns can be understood in these terms, if one assumes that each single movement reflex evokes its counterpart, that each component sets off its successor in time (reflex chain theory). The higher forms of behavior, which are modifiable through experience, are subsumed under the same rubric by way of "conditioned" reflexes."

However, for many behaviorists this is not the case. For them, the notion that the CNS is an active body in which occurrences are possible without external stimulation, appears to be unscientific. For instance, if we take that rest and sleep are but special forms of CNS activity, it would be difficult to restrict everything to this idea that "cause" of every central incidence is still assumed to be "the stimulus." However, von Holst and Mittelstaedt believe that this theory could be rejected due to resistance and laziness of our limited thinking system. They encourage us to see the situation from a completely different angel.

von Holst and Mittelstaedt began by asking the following question: 'How can organisms respond differently to exafferent and reafferent stimuli, even when these are quantitatively and qualitatively alike and when they are superimposed in the same channel? For instance, how do animals overcome stabilizing reflexes during voluntary actions? Take, for example, the stability of space by our vision. If you start moving eyes passively up and down, objects also become unstable and you feel they are moving. Also, patients who suffered from a brain injury are no longer capable to move their eyes, also experience spatial instability. Or, hand-eye coordination in young children— the ability to use their muscles and vision in tandem. It necessitates the development of visual skills, like visual acuity, and muscle skills. When the two work together in a coordinated way, young children begin to increase their ability to pick up, hold, and manipulate objects. As you have noticed, for experiencing a stable vison, voluntary impulses and visual signal have to be coordinated.

To answer above-mentioned question (how organisms differentiate between exafferent and reafferent stimuli), I always use this scenario: let's Imagine a gazelle struts through the forest. As it moves, bushes brush against its skin, leaves rustle at its feet, and arrays of light and shade alternate across its eyes. In principle, the gazelle should be frightened by these sensory events. The activation of its skin receptors could be decoded as due to an insect landing on its skin and the sounds and shadows as due to a predator approaching. Surprisingly, the gazelle does not find these sensory events frightening; they are expected. How is it so? How does organisms' central nervous system (CNS) cope with this enormous flood of information during behavior and differentiate reafferent from exafferent sensory activity? To answer this question, I can say that it is partly because all organisms have access to an internal report of their own movements which can be explained by the principle of reafference in an anticipatory way.

It should be noted that their theory is not restricted to organism's movement. They bring another illustration in performing the principle of reafference which can be traced in visual processing and its relation to memory. The traditional notion of visual processing affirms that

when we identify an input (afference) *as* something, we compare our perception of a new stimulus with items stored in episodic memory. It is analogous to finding a book in library. However, this system does not function for some who suffer from a visual agnosia, a condition in which patients are unable to recognize the class to which an object belongs. These patients have difficulty recognizing a variety of visually presented object. They cannot name them and group them into semantic categories. Remarkably, these patients can also copy drawing of objects and they can match the pairs of drawing as the same or different (very slow in comparison to healthy subject) even using objects they do not recognize. It seems these patients have normal visual input processing but the stored memories hypothesized to be damaged.

As the closing comments in the principle of reafference section, I should maintain that the reafference principle can be applied throughout the CNS from the lowest mechanisms such as internal and external control of the limbs, relations of diverse parts of the body to each other to the highest like orientation in space, perception, illusions, and many others. Furthermore, I believe that it can bond "low level machinery" nerve physiology, to the "high level system" in science of behavior.

Corollary Discharge: Roger Sperry coined the term "corollary discharge" in 1950 by studying fish. In Sperry's experiments, one of the fish's eye was covered and the other rotated by 180 degree (by a surgery). Sperry came to this conclusion that he had reversed a motor signal which has projected back onto sensory processing and accordingly has led to the circling movement of the fish. Having done this experiment, he proposed the "corollary discharge" hypothesis. The idea of the corollary discharge is rather simple: a copy of the signal sent to motor neurons is also sent to other regions of the brain to inform them of the impending movement. In other words, once we begin a movement, a motor command of that movement is sent to the motor system. Simultaneously, an 'efference copy' of that action is sent to the sensory cortex, engendering a 'corollary discharge' of the expected sensory outcome of the motor action. Having compared the expected sensation with the actual sensation, if there exists no discrepancy between the two (so called 'prediction error'), the sensation is experienced. The punchline of these theories is that kinesthetic perception is touched by the motor (efferent) process. This idea had its roots in an obvious observation that our brains consider our own actions when interpreting the world. For example, when we move, the situation of the environment changes considerably and we do not construe the world moving before us, but rather ourselves moving within it. The notion that the CNS effects the flow of sensory information has been debated for many centuries.

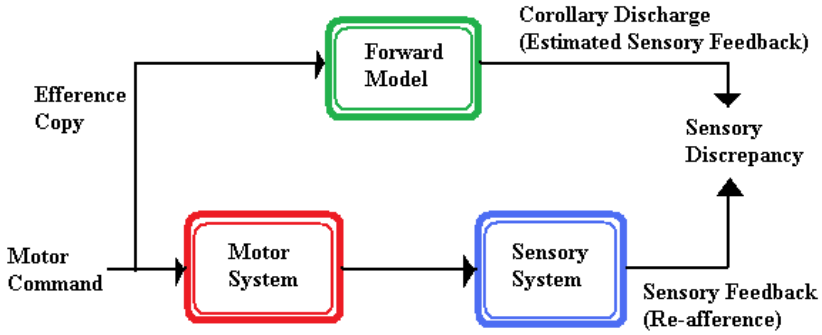


Figure 8: *A schematic view of the corollary discharge.*

Movement is unquestionably dependent on sensory information. We know where and how to stretch for an object because we see its position and structure; we know how much force to exert whilst we are holding the object because we sense the pressure of the object on our hand and the weight on our limb; and we know how to begin any of these activities because our sensory systems say to us where our limb is in relation to our body and the object. Besides, initialing movements is a critical part of everyday life, and it is equally vital that we keep track of movements as we make them. Monitoring our movements aids us to execute complex behaviors quickly and to ignore false sensory inputs caused by movements *(exafferent information).* In recent years, internal predictive models of movement regulation have been tremendously significant in explaining motor control (Wolpert and Miall, 1996; Wolpert and Ghahramani, 2000). For example, blocking somatosensory feedback from a monkey's limb (while leaving motor fibers intact) triggers the limb to go frozen. With training, the monkey can learn to reuse it ineptly, but only with visual feedback; blindfold the animal and motor controller degrades considerably (Sanes*,* 1984). Or, in the somatosensory system, it might elucidate why we cannot tickle ourselves (Blakemore *et al.,* 1998).

There is abundance of evidence that contribute corollary discharge to perceptual continuity and stability in humans and primates. In the visual system, corollary discharge mechanism contributes to the stability of the visual scene during eye movements (Bridgeman *et al.,* 1994). In another example, visual continuity of saccadic eye movements and the role of corollary discharge has been proposed (Wurts and Goldberg, 1989; Deubel *et al.,* 1996, 1998). Furthermore, when we talk, our articulator tissues generate overt speech and the brain by the help of a corollary discharge suppresses the neural and perceptual responses to our speech sounds. Even in our inner speech— the silent production of words in one's mind— corollary discharge functions the same as overt speech. It seems that corollary discharge holds information about the temporal and physical properties of inner speech as the overt one (Ford and Mathalon, 2004; Scott, 2013; Tian and Poeppel, 2010, 2012, 2013; Tian *et al.,* 2016; Whitford and Titone, 2017; Jack *et al.,* 2019). Another example for the vital role of corollary discharge, it has been investigated that the sound of our own voice is used to adjust speech production (if a person becomes deaf, even after learning to speak, their speech becomes impaired (Waldstein, 1990).

Besides that, McCabe and colleagues (2005) examined the hypothesis that pain without obvious associated tissue damage might be caused by discordance between motor intent and movement. In their article, they explained this sensory–motor incongruence and reports of (phantom) pain on the basis of 'corollary discharge' (The principle of reafference).

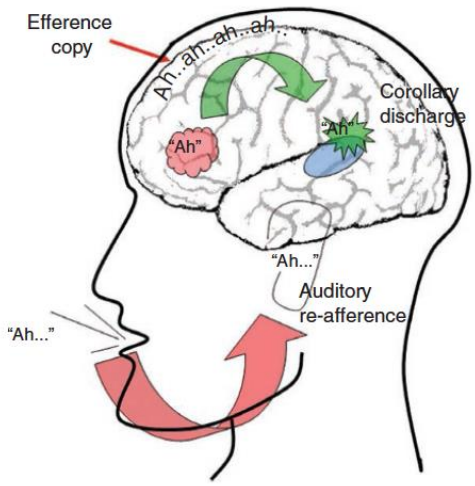


Figure 9: *The picture elucidating corollary discharge mechanism. The notion to say 'ah' is represented as a thought in the speech production areas in Broca area. An efference copy of the motor speech program is then directed from speech production areas to the auditory cortex. A corollary discharge of the expected 'ah' sound is produced in the auditory cortex, signifying the expected auditory consequences of speech. This is characterized as a green burst, overlaid with 'ah' in the picture. An auditory reafference is constructed by the vocalized speech and represented as an 'ah' inflowing the ear. When auditory reafference (what you hear) matches the corollary discharge (what you intended to say), auditory cortical responsiveness is repressed.*

TOTE Model: Miller, Galanter, and Pribram, in their seminal book *Plans and the Structure of Behavior (1960)* proposed TOTE model *(Test-Operate-Test-Exit).* In this model (inspired by cybernetics), they suggested that TOTE should replace the stimulus-response (behaviorists' model) as the basic element of behavior— namely the difference between knowing and doing, or between preparation and performance. In a TOTE unit, a goal is tested (or let's say comparing system) to verify whether it has been achieved and if not, a process is performed to achieve the goal; this cycle of test-operate is repeated until the goal is finally achieved or abandoned. This model was based on this postulation that human actions are primarily organized hierarchically and secondarily in a sequential way. It is worth noting that TOTE model like its processors' ones (the reafference principle and the corollary discharge) signify a crucial role of anticipatory representations for many cognitive processes such as visual and motor control. For example, the discovery of mirror neurons showed that representations are mostly action-oriented and extremely based on the motor machinery (Rizzolatti *et al.,* 1996).

TOTE model is based on this assumption that an organism can create internal "images" in order to compare them against perceptual inputs while vigorously searching for a given stimulus in the environment. Nonetheless, the TOTE is context dependent: it overtly takes the current situation into account in order to regulate the action. One of the examples of a TOTE model is a plan for hammering a nail; in this case, *the test (or comparison)* involves in verifying if the nail touches the surface and *the operation* involves in hitting the nail. In this situation, the representation utilized for the test is in the sensory format, and the operation is always the same, even if the TOTE cycle is comprised of many stages. These two functions (Test and Operation) enable an individual to assess his or her current behavior in relation to a goal; whether to pursue further regulation or unfasten from a goal (exit).

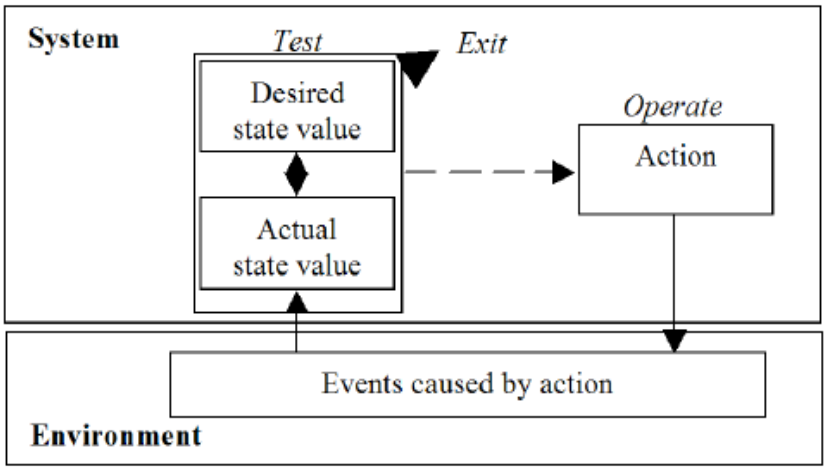


***Figure 10**: A scheme that symbolizes the main features of the TOTE.*

Although it was criticized by many aficionados of stimulus-response camp like Patrick Suppes (1969), TOTE model dominated human–computer interaction and robotics in the next era. Suppes in a very critical way tries to rescue stimulus-response theory in his article in 1969:

"My own conclusion is this: What he has given us is negative dogma not negative proof, and he has not stated a viable alternative to stimulus-response theory. I join with him in acknowledging the central issue raised by the number-of-states problem. The future task for stimulus-response theorists is evident. We must show in detail, for complex substantive examples, just how learning can take place according to stimulus-response ideas."

Despite criticisms, the TOTE model was greatly influential and inspired many subsequent theories such as *the General Problem Solver*— a theoretical framework of human problem solving established in the form of a simulation program which had a significant impact on the subsequent direction of cognitive psychology (Newell and Simon, 1972).

Lastly, most of these theories which have been mentioned (the reafference principle, the corollary discharge, and the TOTE model) consider spatial aspects of movements but temporal aspects have been somewhat neglected. In recent years, lots of motor timing models for actions have been proposed which I will explain them in the next section.

Having explained the most important theories of movement, now, in the upcoming section, let me continue with the second main timing challenge of our brain— the timing of fine body actions (motor timing):

Have you contemplated how does a dancer achieve accurate motor timing under various conditions? We take for granted how humans synchronize their movements with nearby moving things with an outstanding ease. This requires a highly timed processing of the perception-action arrangements underpinning the movement control. Motor activities must be accurately timed for their proper execution which the completing of one component too early or too late could make an action effective. Temporal information in the scope of milliseconds is vital for a wide range of cognitive and motor processes. Time perception is an evolutionary adaptive machinery that facilitates the ability to predict and anticipate events in

an appropriate time, as well as organize and plan sequences of actions for fight or flight. Distinguishing the temporal connexion between visual stimuli, for example, is determinant for the direction and the speed of moving objects. Likewise, the capability to accurately perceive and generate the temporal structures of sounds is essential for the distinguishing and the production of different languages.

According to many studies, perceiving appropriate motor timing and precise timing is vital for the preparation and execution of most motor responses (Buhusi and Meck, 2005). These two play an important role for humans to perform optimally in the environment. For instance, one has to foresee when sensory events will occur and estimate how long these events will endure, in order to move their body, cooperate with others, and act towards environmental stimuli. However, sometimes this motor timing mechanism in which organisms plan in the future with precise timing and foresee the results of actions does not function efficiently. Behavioral and neuropsychological data indicate that hyperactive children, Parkinson patients, and Huntington's disease (Rubia *et al.,* 1999; Freeman *et al.,* 2000) show poor intertemporal competence, i.e., poor ability to associate events, which are separated by time, paced and self-paced finger tapping, and simultaneous and sequential acts.

Also, in prehensile movements proper coordination and precise motor timing of the arm, hand, and trunk is required. For example, when we want to grasp something, time from movement initiation to first object contact and time taken from first contact with the object until the object is touched should be considered. However, precise motor timing of these acts is taken for granted in our speedy life.

In my opinion, one of the reasons that the visual and motor structures evolved together is to support life's acts. Even in oculomotor system — system of eye movements— timing is crucial. For instance, in one type of voluntary eye movements in primates, saccadic eye movements (reading this sentence, for example), the eye position signal initiates to change at least 100ms before the onset of a saccade and does not reach a veridical value until about 50ms after a saccade finalizes (Dassonville *et al.*, 1992; Miller, 1993). It is believed that the cerebellum plays a leading role in timing tuning of acts. This idea originates from this fact that cerebellum have several connections with important cortical and subcortical regions of the brain such as the primary motor cortex (M1), the supplementary motor area, the cingulate cortex, and the basal ganglia. Furthermore, it has been shown that cerebellar lesions lead to behavioral problems on a range of timing tasks (Ivry and Keele, 1989).

In the line of supporting arguments on the importance of precise motor timing, I should mention that if we observe professional athletes' main aim, we notice that they build their careers on motor timing mastery, honing their proficiencies to the very edge of human capabilities. For example, the sprinter must foresee the firing of the starter's gun to get a jump on the competition. How does an individual decode such temporal aims into an action? A wealth of literature on motor timing suggests that temporal control arises, at least in some situations, directly from motor control circuits in the brain (Karmarkar and Buonomano, 2007; Ivry and Schlerf, 2008). Interestingly, many of our tasks have temporal aims or require precise temporal information for their successful accomplishment.

It is worth noting that motor timing is not restricted to the acts in the outside world. Each organism on the basis of its anatomical structures such as jaw or tongue, there should exist a predictable relationship in the relative timing of their movements. Besides, timing in prediction and anticipation should take the form of direct motor behaviors, such as anticipatory licking or blinking. As I mentioned earlier, even in these internal activities, controlling movements fundamentally encompasses activating motor units at the right times. As a matter of fact, a motor learning mechanism without considering temporal specificity

would be a poor one. For example, a bird (to pick up a piece of seed) must open its beak and close it exactly at the moment when the beak surrounds the target. We notice that it is an action which must be precisely timed if it is to be a successful act (Klein *et al.,* 1985; Bermejo, Houben and Zeigler, 1998). Or, in another example, in language impairment studies, evidence is indicating that fine-grained temporal integration in language system is fundamental to speech and language (Cooper and Allen, 1977; Vargha-Khadem *et al.,* 1995; Boutsen, Brutten, and Watts, 2000; Luc, Kroll and Houle, 2001). The impairment in certain aspects of speech and language such as stuttering could be due to impairment in precise vocal timing and perhaps also in intonation abilities among these persons.

Our most detailed neurobiology of time in sensorimotor function comes from experiments in animal models. These experiments have shown how neural activity in various cortical and subcortical brain regions underwrite to the overall ability of an animal to produce timed behaviors (Mauk and Buonomano, 2004; Merchant *et al.,* 2013).

In fact, brain regions underlying cognitive process such as attention, memory and decision processes work together with the neural timer as part of a network serving accurate timing of movements. According to some studies (Ivry, 1993), two brain regions involved in this network—the cerebellum and prefrontal cortex. Ivry and his colleagues (1993) hypothesized that the cerebellum function as an internal clock that serves to time precise temporal associations between events in both motor and perceptual domains. For instance, in dysmetria— a kind of *ataxia* which is a neurological deficit, there is a lack of coordination of movement characterized by the undershoot or overshoot of intended position— is due to dysfunction of the cerebellum. Or, in another study, Ivry and his colleagues (1989) reported that patients with impaired cerebellum are unable to judge the accurate duration of an auditory stimulus.

Likewise, the supplementary motor area (SMA) has generally been assumed to play a prominent role in the coordination of the homologous limbs. However, this could not be the whole story because coordination of limbs needs accurate timing. It is believed that the cerebellum is generally responsible for motor timing synchronization— integrate motor commands and sensory information to help coordinate movements (Braitenberg, 1967; Ivry, 1996).

In recent years, imaging studies have linked a large number of brain areas in motor timing, including basal ganglia (insights from studies on Parkinson's disease), cerebellum (especially Purkinje cells as inhibitory projection neurons), and several prefrontal cortical structures (Ivry, 1986; Poizner *et al.,* 2000; Avanzino *et al.,* 2013). However, some researchers believe that it is not appropriate to restrict motor timing to a specific region. They have proposed the cortical circuits which function in motor timing. They argue that in the temporal control of behavior likely span the whole spectrum from sensory cortex, to higher-order associative areas, to motor cortex. For example, information about the predictable time of sensory events such as visual signals have been detected in primary visual cortex of monkeys and rats (Shuler and Bear, 2006; Sirotin and Das, 2009; Chubykin *et al.,* 2013; Gavornik and Bear, 2014). These findings suggest that primary visual cortex may have a leading role in the construction of visually cued timed actions.

Another criticism which levelled at motor timing research is that many of these experiments are very much like finger tapping tasks. It seems that for the researchers of this field, a hammering motion of a finger an up-and-down motion of the jaw are very similar. However, some believe that persons who are stable timers in a tapping task are not necessarily stable timers when they perform a drawing task. In other words, there is no meaningful correlations between tapping and drawing in terms of timing precision. This notion suggests that timing

behavior is exclusive to the nature of the task, and thus weakens the idea that timing is a generalized capability that can be executed on diverse types of tasks (Robertson *et al.,* 1999; Zelaznik, Spencer, and Doffin, 2000).

Having highlighted the vitality of motor timing in organism's survival, many other questions still arise: how does the brain know the right timing for an action? How does the brain perform such a relative accurate timing with which human and non-human animals are able to survive in complexities of the outside world?

Models of Motor Timing:

Before presenting different models of motor timing, it should be noted that there is an important distinction between motor timing and sensory timing in behavior studies. Sensory timing usually implicates perceiving subjective time and estimating elapsed interval durations defined by stimuli, whereas motor timing involves subjects to produce a precise temporally action pattern. It is worth noting that we should distinguish these two systems of timing in the brain. So, according to motor timing experiments three wide-ranging classes of models of motor timing have been proposed: (1) oscillator-based models; (2) ramping models; and (3) population clocks.

Oscillator-Based Models: This model has a basis on internal clock or pacemaker-accumulator models (Creelman, 1962; Treisman, 1963). In other words, this model follows the principles of man-made clocks in which an oscillator produces periodic events that are integrated or counted by an accumulator. It is important to note that there exists very little biological support for the standard pacemaker-accumulator models. However, it has been well recognized that oscillators do contribute to timing of rhythmic motor activities. It seems that the difference lies in the distinction between supra- and sub-period timing (above and below the period of the time base). Many rhythmic motor behaviors that necessitate firmly timed sequential responses—such as walking, breathing, and swimming—are administered by the phase of neural oscillators (Marder and Calabrese, 1996; Grillner, 2003; Feldman and Del Negro, 2006).

Ramping-Based Models: It refer to a neuron or population of neurons which endure a nearly linear increase (or decrease) in firing rate over time, consequently producing a metric of lapsed time encoded in neural firing rate. There are plentiful data exhibiting that, during interval motor timing tasks, neurons in the parietal cortex (Leon and Shadlen, 2003; Janssen and Shadlen, 2005; Jazayeri and Shadlen, 2015), prefrontal cortex (Niki and Watanabe, 1979; Kim *et al.,* 2013; Emmons *et al.,* 2017), and premotor and motor cortex (Mita *et al.,* 2009; Murakami *et al.,* 2014) all show almost linear ramping of firing rates during motor timing tasks. Importantly, the slope of the ramp usually decreases as the interval being timed increases, while the peak firing rate rests approximately the same (Leon and Shadlen, 2003; Murakami *et al.,* 2014; Jazayeri and Shadlen, 2015; Merchant and Averbeck, 2017). While there exists plentiful experimental evidence that many neurons exhibit ramping firing rates during timing tasks, many issues have remained unsolved. In addition to whether ramping encodes time or motor preparation, it is not clear whether ramping suggests the timer per se or is formed by fittingly tuning the weights of upstream neurons that encode time through altering patterns of neural activity (Laje, Cheng and Buonomano, 2010).

Population Clocks: In this model time is encoded in the changing population of neurons (Buonomano and Karmarkar, 2002). Hence, population clocks rely on a general feature of neural circuits—their internal neural dynamics. Population clock models suggest that a given neural circuits encodes time from the beginning of a given stimulus, or depending on the context. The population clocks have been detected throughout the brain, including parietal cortex (Nelissen *et al.,* 2013; Crowe *et al.,* 2014), premotor and motor cortex (Carnevale *et al.,* 2015), frontal cortex (Wang *et al*., 2018), prefrontal cortex (Bakhurin *et al.,* 2017), the basal ganglia (Jin *et al.,* 2009; Gouvea *et al.,* 2015; Mello and Stoodley, 2015; Bakhurin *et al.,* 2017), hippocampus (Pastalkova *et al.,* 2008; MacDonald *et al.,* 2011). In many of these findings, it has been confirmed that the speed of the population clock co-varies with behavior.

(3) S*ubjective time*

Time is the currency of life, a means through which we experience life both significant and pleasurable. Furthermore, when we talk about the relation between time and our brain, we should also consider the concept of subjective time. Other theories regarding the relation of subjective time to the brain declare that subjective time is not a unique property of the human brain rather subjective time perception is ascribed to memories and future imagery as a means of preserving some level of organization for our thoughts (Jacoby and Brooks, 1984; Hassabis and Maguire, 2007). Perception of time – the way we subjectively experience time, what time feels like to us as individuals – is a boundlessly interesting topic because time persistently surprises us; a good holiday races by, yet the moment you arrive home, it feels as though you have been away centuries. How is it possible to have such a feeling of the passage of time?

The basis of conscious life seems to be subjective time. Understanding subjective time is understanding something that is fundamental to humanity. It is a necessary condition for the foundation of our psychology and concepts of reality. Moreover, it is part of the cerebral structure by which we perceive the temporal sequence of events in our lives. Our survival depends on our capability to track complex processes in an appropriate time and anticipate change. The discussions about subjective time began by namely the *Confessions of Augustine* with this famous quotation on time: “What, then, is time? If nobody asks me, I know it; if I have to explain it to somebody, I don't know it.” It seems that Augustine’s statement about time inadequate and self-contradictory. In fact, he is unable to give us a satisfactory response. It is like a setting someone asks us to describe the ineffable taste of sour cherries, yet here again we should say ‘I do not know’.

Nevertheless, how do we perceive duration of time? It is assumed that human subjective time perception functions in two ways: a cognitive process which we judge time by the use of indications, or *Mother Nature* has set an internal clock in us that generates temporal information. Many scholars have pursued evidence for the existence of such a clock. Hence, if there is such a clock, conscious awareness of elapsed time strains that the brain has both measure time mechanism, and keep a controlling memory of how much time has passed. Remembering the passage of time or what so-called *subjective time* has been scrutinized by psychologists and neuroscientists through past and present era. Of course, the terms ‘time’ and ‘temporal processing’ in psychology and neuroscience involve a broad range of

phenomena, such as simultaneity (“perceptual moment”, “specious present” or “a psychological now”), temporal order and the subjective perception of time duration. In this section, I concentrate on the last of these which seems critical in my future arguments on the importance of time.

A first empirical answer to the question of how long a moment is for humans was probably given by Ernst Mach in 1865. His main interest focused on the discrimination of different time intervals. He endeavored to establish a simple psychophysical law to study different feeling of temporal perception in the auditory modality. In his experiments, he discovered that there is no experience of duration for intervals of 40 milliseconds or shorter. Karl-Ernst von Baer reaches the same result (He calls it “moment”) years before Ernst Mach’s discovery. Interestingly, it is probable that Ernst Mach has not been informed of the speech delivered a few years ago by Karl-Ernst von Baer about this topic.

Later on, in 1927, one of the students of Henri Piéron – Marcel François – undertook a series of experiments in order to demonstrate that time measurement varies on the basis of ‘‘physiochemical’’ mechanisms. He ran a technique known as diathermy— implementing high-frequency electric currents through people’s bodies in order to raise their body temperature. Having done this on his participants, he attempted to test the effect on time perception. His results confirmed that an increasing body temperature prolongs time estimates (François, 1927). Since then, abundant studies relating keeping participants in overheated places or putting them in baths of cold water have formed evidence in support of a correlation between body temperature and the rate of subjective time.

Nowadays, there is an effort among psychologists and neuroscientists in subjective time estimation. This requires the participants to employ an internal clock in order to gauge objective time without the advantage of cues from external clocks. They aim to find an ‘‘internal clock’’ within the brain— an internal mechanism that is assumed that it is responsible for time measurement. However, the “internal clock” and “subjective time” sometimes become a controversial topic among scientists because these two notions are intermingled with other cognitive processes such as attention and memory. Thus, it should struggle to describe its own identity and to detach itself from the study of other cognitive procedures such as attention and memory. The concern is, for instance, in interval timing task in the seconds to minutes range (very common experiment among psychologists and neuroscientists in order to find neuronal mechanism of subjective time) may be the by-product of other cognitive processes such as memory and may not possess its own major characteristics or underlying neural mechanism. However, the situation is not as gloomy as it appears. Fortunately, recent discoveries in the documentation of interval-timing dysfunctions in a variety of neurological and psychiatric disorders as well as finding brain machineries specialized for the encoding of stimulus duration, interval timing has become accepted as a basic component of cognition.

There are plentiful reasons to suppose that humans and other animals have a well-developed sense of time perception in the seconds-to-minutes scope. Evolutionarily speaking, time are important for making predictions in the environment, for example, about the presence of predators or prey. For example, millisecond time perception is vital for motor control and rapid sequencing of cognitive processes, such as updating working memory and language processing. Furthermore, humans are outstanding at interval timing and sequencing. They can make fine temporal discernments and are sensitive to slight perturbations in rhythm and musical structure (Epstein, 1989).

It seems that our time perception is very fragile. Sometimes we have peculiar impressions of time. In other words, subjective time is not isomorphic to physical time: the subjective

duration of an event can be thoroughly overestimated, a phenomenon referred to as ‘‘time dilation’’, ‘‘time subjective expansion’’ or ‘‘chronostasis’’. For instance, “watched-pot phenomenon” (Fraisse, 1963), where time seems to dilate is the best proof. Besides, James’s comment (1890) on the paradox of time is expressive in this sense:

‘‘In general, a time filled with varied and interesting experiences seems short in passing, but long as we look back. On the other hand, a tract of time empty of experiences seems long in passing, but in retrospect short’’

Likewise, human folklore contains lots of these expressions which relate to dilation and compression of time: “Time waits for no man”, “watched pot never boils”, or “the heaviness with which time hangs on one’s hands”. Likewise, we have all experienced that in horrible events seem to “last a lifetime.” Time appears to speed up, slow down, or even stop. When people become depressed, for example, they experience a slowing down of time, such that ‘‘a day feels like a year’’ (Ratcliffe, 2012).

In everyday life, time fluctuates according to our emotional circumstances. Time seems to fly when we are beside the one who love and to drag when we are bored. Why are there these distortions of time? How can psychology and cognitive neuroscience explain it? It seems that there is a difficulty for researchers to clarify these subjective distortions of time. However, compression and dilation of time is a very interesting topic in time perception theme in psychology and neuroscience. Moreover, a generation ago, study of timing was limited, emphasizing the investigation of behaviors. More recently, a revival has taken place in the study of subjective time perception, with researchers tackling with a broad array of temporal phenomena. Labors in psychology and neuroscience of time are often accomplished to determine how accurately ‘real’ time is perceived. In pursing time in these sciences, the concern is with experiential time; per se, not as it might relate to hours, days, or to some other time definition.

According to a study done by Oliveri and his collaborators (2008), perception of time duration can be compressed and expanded depending on the degree of magnitude of numbers: when stimuli are comprised of digits, small digits time estimation is towards short durations whereas large digits time estimation is towards long durations in a behavioural standard time comparison task. According to this study, the digits which influence on our time perception seems to be precisely related to the quantity expressed by the digits. This result brings up a question whether our visual system also plays a pivotal role in time perception. Clearly, we lack a sensory structure dedicated to the sense of time such as vision or auditory organs. Nevertheless, many of our percepts, and our movements in response to these percepts, are intensely dependent on the precise representation of time. Investigations on subjective time showed that saccadic eye movements result in a ‘chronostasis’—a type of temporal illusion— which is an increased perceived time duration of visual stimuli near the destination of the saccade (Yarrow *et al.,* 2001). In line of this argument, Suzuki and his colleagues found that there exists a correlation between pupil size and subjective passage of time in non-human primates (Suzuki *et al.,* 2016).

The bulks of studies have documented a notable body of neuropsychological evidence supporting the postulation that emotions are tangled in most, if not all, cognitive processes (Damasio, 2011). Although an increasing number of reports have explored the role of emotions in cognitive activities, only a limited number of studies have examined the association between emotional states and estimation of time durations. What is the underlying mechanism regarding the nature of emotions and subjective time perception? In a study, Dan Zakay and his colleagues (2014) investigated the influence of exposure to threat

versus neutral stimuli on time perception in anxious and non-anxious individuals. Results indicate that relative to non-anxious individuals, anxious individuals subjectively experience time as moving more slowly when exposed to short (2-second) presentations of threat stimuli, and that group differences disappear with longer exposure durations (4 and 8 seconds).

In the line of emotional factors, it is also argued that the link between sense of subjective time and mood states plays a fundamental role (Wittman and Paulus, 2008). For instance, impulsive subjects devalue temporally delayed rewards more toughly than do comparison subjects, and this behavior might be owing to their altered sense of time. Despite all of these speculations, mystery lasts to grasp the underlying mechanisms by which mood disorders impact time perception.

Furthermore, a person suffering from depression frequently says “Every hour seems a year to me” or “Time, it’s terribly slow.” There is the sense that time is passing more slowly than normal in individuals with symptoms of a depressive mood disorders (Bech, 1975; Hoffer and Osmond, 1962; Kitamura and Kumar, 1982; Blewett, 1992). Among many findings, in one example, Elsass and his colleagues (1979) showed that time estimates differed between lithium-treated bipolar patients and untreated individuals. This work has since been advanced by other neuroscientists in following years.

Likewise, Rammsayer (1990) found out that schizophrenic patients have poorer time discrimination than healthy subjects. In another experiment which was done in my lab in the *Institute of Medical Psychology* in Munich (LMU), Khashabi (1990) reported the same results. Additionally, the results propose that children with ADHD act poorly on time reproduction tasks. They also suggest that these children may have a perceptual shortfall of time judgement, which may only be noticeable in brief durations which vary by several hundred milliseconds. A subjective temporal perception problem in the range of milliseconds in ADHD may influence other cognitive functions such as language skills and motor timing. (Smith *et al.,* 2002). It is also predicted that social exclusion and suicidal patients should alter the subjective perception of time flow. For instance, when asked to estimate how much time had passed during 30-s and 60-s durations, suicidal patients overestimated the amount of time that had elapsed (Neuringer and Harris, 1974).

Amnesic patients have also trouble estimating time intervals greater than 10-15 s. There are studies which indicate that memory disorders (Wernicke-Korsakoff syndrome, Alzheimer’s disease) are strongly related to imperfect accuracy in time estimation (Nichelli *et al.,* 1993). Likewise, it has been reported that patients with Parkinson’s disease are poor in estimating and reproducing time intervals in the range of seconds. This problem is more severe when subjects are requested to count internally during the intervals. However, Riesen and Schnider (2001) showed that the Parkinson’s disease patients estimated time intervals up to 48 s as precisely as the controls.

Additionally, in adult humans, Watts and Sharrock (1984) discovered that individuals suffering from arachnophobia— is an intense and unreasonable fear of spiders and other arachnids such as scorpions— judged a 45-s period looking at a live spider to endure longer than nonphobic individuals did. In another study, Gil and Droit-Volet (2011) tested the effect on time perception of angry faces versus neutral faces. They found that negative high-arousal pictures are perceived of as lasting longer than neutral low-arousal ones. Also, Gorn and his collaborators (2004) investigated that how screen color in a website affects subjective time perception. The authors examined the relation between the color of a Web page’s screen while the page is downloading and the seeming speed of the download. Their findings propose that colors that prompt more relaxed feeling conditions lead to greater perceived quickness.

According to these findings, it seems that our sense of time is distorted by our emotions to such an extent that time appears to fly when we have fun and drags when we are bored. There is an agreement that timing and subjective time perception not only involve cognition but are also closely linked to our emotional life (Droit-Volet *et al.,* 2013). Nonetheless, the nature of the mechanism underlying the extending outcome of these emotional stimuli is still unclear.

What about subjective time investigations on children? It seems that subjective time perception among children varies on the basis of their age. Moreover, their sense of subjective time depends on emotional variables (Gil *et al.,* 2011; Droit-Volet, 2013). For instance, in a study done by Gil and his colleagues on children aged 3, 5, and 8 years, they realized that in all age groups, children estimated the duration of angry faces to be longer than that of neutral faces.

Distortions of time are also often described after accidents and frightening happenings, when individuals experience a slowing down of external events, as if the outer world, relative to were moving in slow motion. There is abundantly anecdotal evidence of a slow-motion situation in extreme danger which is stated by people who have rescued from that situation: 'I saw a truck approaching my car and yet, since all external events seemed to unfold as if in slow motion, I had time to involve the clutch, shift, and accelerate, thus managing to avoid a terrible accident'. Yet, it seems the situation is paradoxical; while the brain functions more quickly in a dangerous setting, the outside world appears to be moving more slowly. How could it be possible? In fact, the mechanism of such an acceleration in the inside world (the brain) has been explained quite straightforwardly which has been associated to the activation of the *locus coeruleus* norepinephrine system (the *locus coeruleus* is the principal spot for brain synthesis of norepinephrine as an excitatory neurotransmitter). But, the slow-down theater of the world outside is still a mystery.

Pharmacological studies have also indicated that the administration of drugs that surge the level of dopamine in the brain extends subjective time and effects on the estimation of time (Yanakieva *et al.,* 2019). For instance, the administration of psychostimulants, such as cocaine and methamphetamine, upsurges arousal and generates an overestimation of durations, whereas the administration of antipsychotics, such as haloperidol and pimozide, declines arousal and produces an underestimation of intervals. Furthermore, it is common understanding that the drunk man is usually disoriented as to time as well as space. Marijuana also generate a somewhat similar effect. Interestingly, orchestra leaders and drummers (I have heard from them) sometimes smoke some psychedelics with the idea that it helps them in rapid timing.

Likewise, in the realm of attention studies, a broad literature offers evidence for the hypothesis that attention plays a role in the estimation of time duration and it may be induced by properties of environmental stimuli (James, 1890/1950; Mattes and Ulrich, 1998). According to them, attention can overestimate (or underestimate) the perceived duration of an element of objective time (1 second, for example).

What about subjective time perception in animals? There are lots of studies on animals in this realm. In a classic study, using a multiple-choice device, Hunter (1787) measured the time that could pass between the exposing to a light before the correct choice box and the release of the animal which would result in the animal going to the correct box. In the three-choice box, Hunter discovered that for rats it took from one to ten seconds to find the correct box, but the average time was not much more than one second. He repeated the same experiment on dogs and racoons. For dogs the time averaged about ten seconds and for raccoons it averaged about 20 seconds.

In another experiment Woodrow (1928) taught two monkeys to discriminate between temporal intervals of 1.5 and 4.5 seconds. They were taught to reach for food upon the removing of a screen after the longer but not after the shorter interval. The monkeys became 90 per cent correct for these time intervals and 75 per cent correct in discriminating between 1.5 and 2.18 seconds. Additionally, Walton and his colleagues (1981) used a different kind of choice box took delays up to one minute in dogs. Yarbrough (1917) found from two to four seconds delay in cats on a three-compartment maze. Several authors have studied time responses in invertebrates such as wasps, bees, and ants (Verlaine, 1929; Anderson 1932). In brainless organisms, it seems the situation is the same. They have a precise sense of time and decide on its basis (Reid *et al.,* 2016).

Although the clock hands round at the same rate for all observers, all these experiments imply that time seems more hastily moved towards one individual than another. The level of the person's activity is thought to be the most important factor in the subjective speed of time, not the value of time. It does not seem that this law works for elders. Old age is a situation in which time is more expensive than before although the elderly are less busy and active. As death approaches, time runs out for the elderly. It may be because of the limited time left that allows them to stick to life and regrets. In contrast, time is less distressful for the younger adult. He still assumes to have a great deal of it, thus as a commodity time is comparatively cheap.

Lastly, I should mention that all of these findings show that time is ubiquitous in all organisms' behavior and they have emphasized how the temporal structure of events controls our perception of the world. There is an immense literature in social psychology for instance, as to how behavior is formed by time which contains topics such as time management, time perspective, and time orientation, or the relative value of past and future (Zimbardo and Boyd, 1999; Perret-Clermont, 2005; Strathman and Joireman, 2005; Caruso, Gilbert, and Wilson, 2008). Besides, in sensory science—a scientific discipline which attempts to arouse, measure, analyze and unravel responses to products perceived through the senses of sight, smell, touch, taste and hearing— it is reported that time perception plays an essential role in eating, since it regulates the dynamics of food oral processing (bite, chewing, swallowing and clearance) and the appreciation of food sensory properties (Taylor, 1996).

4.3. Neuronal Mechanism and Timing Models of Subjective Time Perception

Is our perception of the passage of time the outcome of devoted, clock-like neural mechanisms? Or, is it an intrinsic and ubiquitous feature of neural activity? In fact, underlying neuronal mechanism of time perception has become a heated topic in recent years. Historically speaking, a classic case study of the neuropsychology of time perception comes from the popular individual H.M., who underwent a bilateral medial temporal lobe removal surgery that resulted in a severe memory loss (Milner and Penfield, 1955). When H.M. was asked to reproduce durations ranging between 1 and 300 s, he showed reasonably accurate time perception for durations <20 s, but systematic underestimation for durations >20 s. This discovery renewed interest in the lateralization of temporal processing in later years.

Lots of models have been proposed that how the ''internal clock'' functions in order to account for the full understanding of time perception. For example, the proponents of *modular models of time* argue that as vision scientists speak of dedicated mechanisms for

color or motion perception, modular models of time also require some sort of particular mechanism that embodies the temporal relationship between happenings. *The pacemaker-counter model* is one example of these presented systems (Treisman, 1963). In this model, these two constituents (*pacemaker* and *counter*) define a clock with a gap specified by the accretion of inputs from a pacemaker. *Spectral model* is another example of these modular systems of timing (Miall, 1989; Matell and Meck, 2004).

Another example is *cerebellar timing hypothesis* (Ivry *et al.,* 2002). One incentive for this model comes from the observation that sense of the passage of time acts imperfectly in patients with cerebellar pathology. the cerebellar timing hypothesis assumes that the cerebellum has a unique representational capability and is retrieved whenever a particular task needs precise timing. Similar arguments have been advanced for other neural areas that might assist as dedicated timing systems such as the basal ganglia (Harrington *et al.,* 1998; Rao *et al.,* 2001), supplementary motor area (Coull *et al.,* 2004; Macar *et al.,* 2006) and prefrontal cortex, especially in the right hemisphere (Harrington *et al., 1998*; Lewis and Miall, 2006).

However, a compromise has not reached yet according to which the processing of time does involve one simple brain region— not all scientists agree with. Some of them maintain that there is no such thing as a specific time-processing mechanism in the brain. In other words, other models evade from localization issues by suggesting that the representation of time results from a wide range of neuronal activities across a network of regions in the brain.

By having this idea in mind and also advance in studies of time a broader view of timing, which we will refer to as *intrinsic models* were developed. For instance, *distributed timing model* is one of them. This model shares this notion that timing is 'distributed' across many brain regions efficient for temporal processing; and that circuit depends on task, sensory modality and lengths of temporal durations (Harrington *et al.,* 1998; Lewis *et al.,* 2003; Durstewitz, 2003; Ivry and Spencer, 2004; Karmarkar and Buonomano, 2007; Ivry and Schlerf, 2008). The most noticeable feature of this model is that temporal representation is context dependent. For instance, the network's representation of the duration of a tone is linked not only to activity happening during the presentation of the tone but also to the state of the network at the onset of the tone.

4.4. Subjective Time Perception in Musical Imagery: an fMRI Experiment

In pursuing time perception and finding a new model for subjective time estimation (STE), I made an experiment on subjective time perception in imagery, or better to say time perception in *musical imagery*.

To the best of my knowledge, subjective time estimation in imagery has not been investigated in recent years. Most of subjective time duration tasks are divided into two the methodological approaches: prospective and retrospective research paradigms. In the prospective paradigm, participants are explicitly informed in advance that they will be obliged to judge the duration of an interval. In this procedure, participants presumably monitor the passage of time consciously and concentrate on any available temporal cues. In contrast, the retrospective paradigm is based on not given any prior warning about time judgments. These subjects are unexpectedly asked to judge the length of the interval after it has already passed

by. Subjects should process temporal information in a more incidental and unreliable fashion. Our experiment which is nearly similar to a retrospective approach aims to find a different pattern in brain in imagery subjective time perception.

It is worth noting that one of the advantages of imagery experiments is that the focus of participant's attention is optimally on their inner subjective experience. Likewise, I realized that most of subjective time estimation tasks are mostly based on reaction time and it is directly related to the amount of attention assigned to the passage of time. So, there should be another way to investigate subjective time in human— a contextualistic approach to temporal processing. In other words, just as context interact to determine our subjective experience in general, so in the particular case of temporal experience. But in the experiment, the imagery context was the case. Our purpose in this experiment was to explore the subjective time estimation in musical imagery and its underlying brain mechanism. I was also interested in seeing whether I can find a common brain circuits in each imagery task. The experiment has been done as follows:

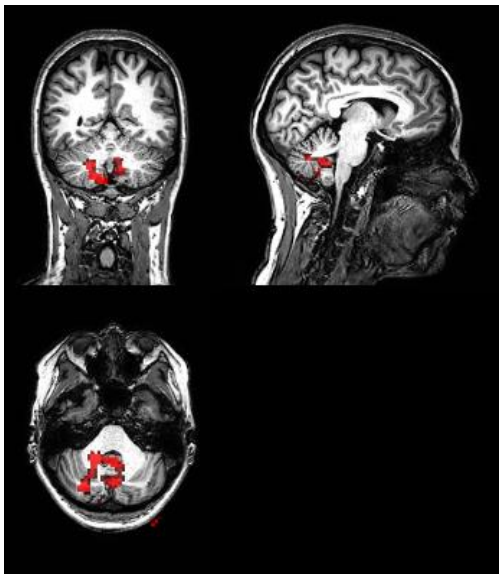
Methodology and Procedure: I invited 10 professional violinists and asked them to play a short piece in realty (live). We recorded the time duration of their plying. Then, we asked them to play the same piece in their imagery in MRI machine. The task was comprised of two conditions: i) continuous (they should have played their chosen piece of music in imagery from beginning till end continuously) ii) interrupted (while they began playing the piece in their imagery, they were interrupted by timing intervals of 2, 3 and 6 second beeps). The subject was required to pause while they heard the beeps and then continues playing.

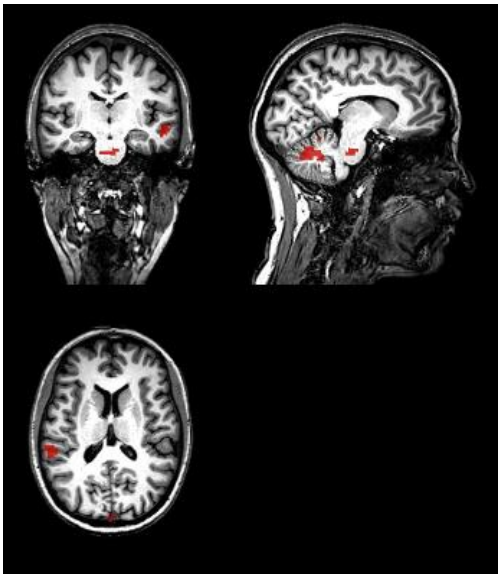
Result (behavioral): Their different timing estimation of realty and imagery in two conditions (continuous and interrupted) was quite worth noting. I realized that the lengthy pieces which were played in reality, they were underestimated in imagery, but the shorter ones, mostly were overestimated. It seems that Vierordt's effect was also observed in time estimation in imagery as it is seen in reality.

Result(fMRI): I noticed a high brain activation in the cerebellum in both conditions (also other regions like Right Planum Polare and middle frontal gyrus (Figures 4.8). It seems that the brain traces the time duration in reality and also imagery without being disturbed by external stimuli. There exist lots of experiments which confirm the activation of cerebellum in supra-second time estimation tasks. It is surprising that I have witnessed the same activations in imagery tasks. Mirror neuron effect was also observed in this experiment. I bring some of the participants' brain activations.

Participant: M.S
Played piece: Mozart D-Dur Violin Concert
Music piece duration (In reality): 2: 20: 40ms
Music piece duration (In imagery):
Continuous: 1: 54: 52 ms
Interrupted: 2: 27: 50 ms

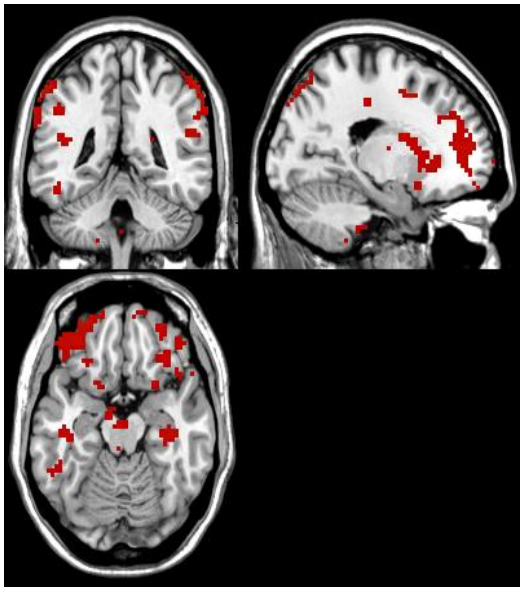
Most Activated Brain Region(s)	
Continuous Condition	**Interrupted Condition**
Right Planum Polare *Left Cerebellum Exterior*	*Left Cerebellum Exterior* *Right Cerebellum Exterior*

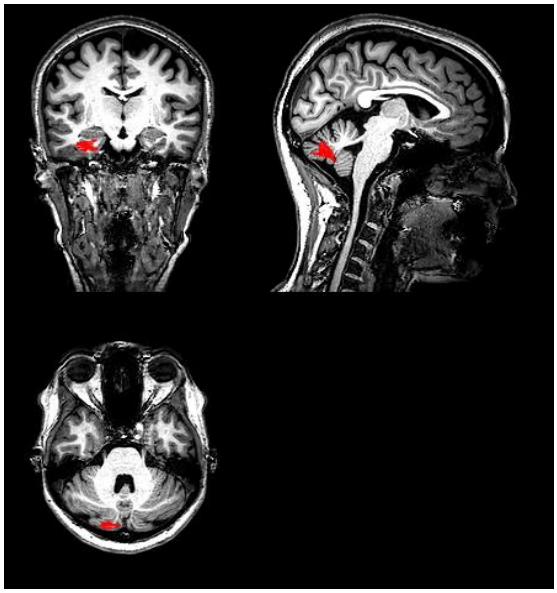




Participant: M.P
Played piece: Bach Sarabanda (2nd partita)
Music piece duration (In reality): 3:18: 37 ms
Music piece duration (In imagery):
Continuous: 4: 21: 46 ms
Interrupted: 4: 24: 21 ms

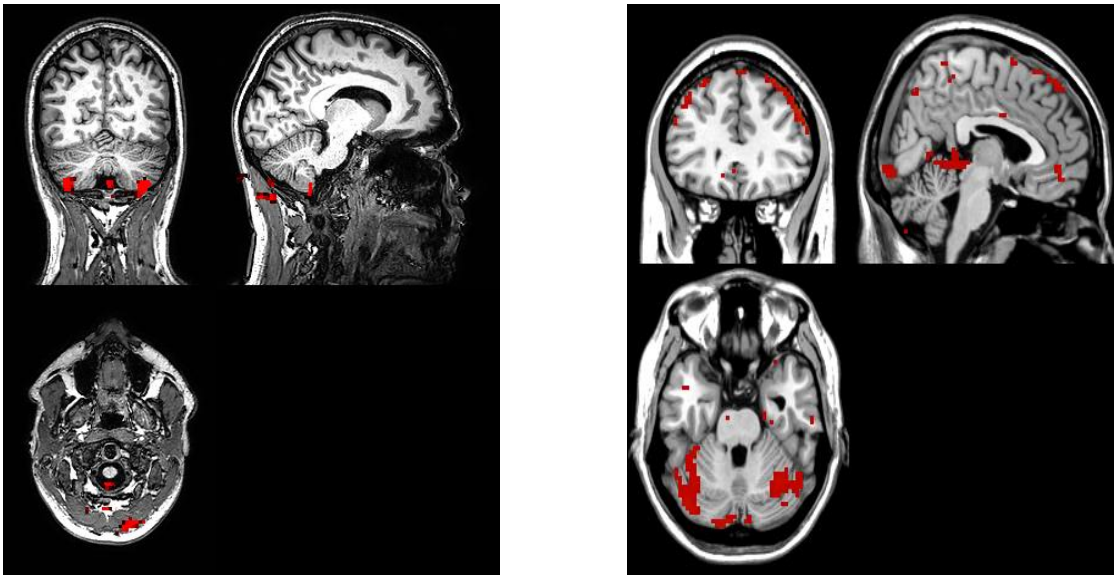
Most Activated Brain Region(s)	
Continuous Condition	**Interrupted Condition**
Left Middle frontal gurus *Visual Cortex*	*Left Cerebellum Exterior*





Participant: D.T
Played piece: Bach Sarabanda (2nd partita)
Music piece duration (In reality): 3: 12: 73 ms
Music piece duration (In imagery):
Continuous: 4: 16: 32 ms
Interrupted: 5: 50: 99 ms

Most Activated Brain Region(s)	
Continuous Condition	**Interrupted Condition**
Right Cerebellum Exterior *Left Cerebellum Exterior*	*Left Cerebellum Exterior* *Middle frontal gyrus*



Figures 11: *Brain activations of subjective time perception in imagery (three of participants)*

5

FLOW OF SUBJECTIVE TIME: DISCRETE OR CONTINUOUS?

Until we have a firm understanding of the flow of time, or incontrovertible evidence that it is indeed an illusion, then we will not know who we are.

—Paul Davies

5.1. A General Frame

Putting aside the main puzzling issues about where and how consciousness arises, and many other questions such as whether consciousness is physical or non-physical, whether it is epiphenomenal, whether it arises on a gradient (like sunrise, which comes in degrees) or is "binary" (like pregnancy, and is either there or it isn't), whether there is an explanatory gap, whether consciousness is an irreducibly fundamental aspect of reality, and the nature of the relationship between consciousness and intentionality, there still exists an opacity between consciousness flow and its association to time. In pursuing the neural correlates of consciousness, time (how consciousness arises in time) as an important variable has been ignored through history of science and most of thinkers concentrated more on where it occurs. Imagine we have understood the whole mysteries of consciousness and obtained a fine-grained knowledge about the brain network or any other breakthroughs about the underlying mechanism of the place of consciousness. There are still some questions: if we take our brain the emergence source of our conscious experience in a completely materialist term, how does the brain produce it in time? Is consciousness emerged in a continuous or discrete form? I mean that does the brain create it in a smooth, non-stop and

continuous procedure (like when you switch on the engine of a car) or on the other side, the perception is a sequence of discrete conscious instants.

To answer these questions, we should dive into a much deeper parts of the ocean of life. I suggest that we had better begin with the concept of motion as Jean Paul Sartre maintains that everything is on the move and head forward, as a skier who must slide down the sleek slope of snow. Consider, for example, any organism's motion. At the first glance, we notice that motion is the essence of life itself. All living organisms move within the world. This motion could also be within themselves, in the circulation of blood, air and nerve impulses. Plants also move. Although they are rooted in the soil, they also move by bending to the wind, actions of photosynthesis and absorbing nutrients by osmosis. We also do feel motion. The awareness is deeply connected to our emotional experience of movement. We feel we go forward within time and through time. Time itself moves, according to some, with a unidirectional arrow that points only frontward. Moreover, many words in our languages contain aspects of movement (flowing, clumsy, graceful, awkward, and so on). We report our qualitative sense of motion subjectively, by metaphors, adjectives and many other poetic means. Thus, motion is the quintessential property of time. It seems that everything is moving in the universe. Even, entropy, as the critical scientific measure of the capacity of the physical world with spontaneous changes, disorder or chaos is a kind of motion.

As a subjective experience, we move in time like a river, and events vanish into the past. We often call this motion as passage of time— or let me call it *the passage of subjective time*. The world is not to be classified in any particular material, but rather with an ongoing progression governed by a law of change. Heraclitus, the Greek philosopher, is the pioneer of this idea that all things pass and nothing stops. He believed that '*there Is nothing permanent except change*.' For him, change is the only reality in nature. His analogy of the passage of time as the flow of a river is illustrious (*panta rhei*) "everything flows". He says "*No man ever steps in the same river twice, for it's not the same river and he's not the same man."* In plain words, he means that one cannot step into the same river twice because one is changing and the river too. The water one touched earlier will be downstream while one steps in water from up the stream. Just as water flows in a river, one cannot trace the exact same water twice when one steps into a river. Everything is constantly changing. Individuals are never the same, changing in some way from minute to minute to day-to-day experiences. There is a *flow* in which the world continuously changes and no two situations are exactly the same. It seems that every mortal moves ceaselessly in the river of time.

But how we move in time is still the enigma. What is the element that provides our sensation of movement in a smooth way? How is it possible that we perceive these periodic movements as a whole? How does this motion happen in time? Is it continuous like the stream of a river or gappy like a bumpy road? Our intuition says that psychological time is continuous rather than discrete (James, 1890). But it seems that our intuition is wrong. We should be aware that subjective experience of time or intuitionistic understanding of it might not be the best timing gauge (Pöppel, 1996). In fact, what we lack is a qualitative sense of connection between units of time. In other words, we need a scientific explanation of our motion in time. Nevertheless, we should not be hopeless. Lots of new scientific advances in different fields proclaim that continuity is just an illusion. Everything in our world moves in a discrete, gappy rhythm. According to numerous scientific proofs, this motion divides into periodic units to guarantee survival/adaptive strategy and minimize energy expenditure. Surprisingly, the periodic unit strategy is not restricted to living organisms. Much of the world displays periodic movements: packages of energy (quanta), electron spin in the subatomic universe, revolution of the planets on their axes, biological rhythms and so on.

Because this dissertation is about the relation of brain and time— our existence in time, in the upcoming sections, I concentrate on the flow of our consciousness in time (or, flow of subjective time) and whether It is discrete our continuous. It has become very important topic in neuroscience and psychology (also in philosophy of mind discussions) in recent years. In the forthcoming section, I convey some discussions in the course of history about this concept. Furthermore, I will bring lots of findings in neuroscience and psychology that confirm the discrete form of conscious perception.

5.2. A Historical Overview on Different Opinions (Discrete or Continuous?)

All events seem entirely loose and separate. One event follows another; but we never can observe any tie between them. They seem conjoined, but never connected.

—David Hume

Regarding the question of whether consciousness flow in time is discrete or continuous, two camps glitter in this realm: one reflects that there is an undisputable flow in the world (the continuous flow is an in-built mechanism in consciousness which is called "introspectionism") and another (the non-illusion camp) reasons that there is just a block of events. However, the latter argues that although the flow of consciousness is just an illusion, it is not enough to simply dismiss it as a mind-dependent illusion.

Historically speaking, whether consciousness emerges in a discrete form seems not a new question and we can spot the trace of it in the third century BC among Buddhists. We can find in the Abhidharma texts of Buddhist school the idea that perception is actually a series of discrete conscious moments. Moreover, in some near eastern mystical schools like Sufism, especially Rumi and Shabistari's mysticism, the concept of consciousness comes always with the discrete instants from what they call 'the innermost consciousness'. Also, the 13th century Japanese philosopher, mystic and poet, Eihei Dogen, in his life's work Shobogenzo, he explains the nature of time and existence. The chapter starts with a poem that portrays the freedom of each moment of life. From his point of view, time means time is present and time is present. He says:

"Time-present is standing on the mountain heights. Time-present is sinking to the depths of the ocean. Time-present is an angry demon, time-present is a buddha. Time-present is a formal ceremony, time-present is the temple compound. Time-present is an everyday individual, time-present is pervading the whole Universe".

In the western world, Karl Ernst von Baer presented discrete theories of perception in 19th century by devising the term "moment" as the border between the past and the future. In 1865, Ernst Mach showed that there is a perceptual time interval. He discovered that although this time interval exists in human consciousness, it is not perceivable due to some human limits. Also, in 1868, we have Karl von Vierordt who proved the discrete form of consciousness by many empirical evidences.

In the realm of philosophy, Gottfried Wilhelm Leibniz, by examining the notion of substance and influenced by Aristotelian tradition, proposes that all substances are exposed to unceasing change. In other words, that the principle of change is interconnected with substance itself. He believed that nobody in *Nature* is continually maintained in a state of rest. Leibniz once said that nature makes no leap— "*natura non facit saltus"*. It is a principle which it is known as *The principle of Continuity (1687)*. In the second part of *Specimen Dynamicum*, saying that the law of continuity is the fundamental principle of an original and general order in *Nature*, being infinite from the very beginning. He thought that bodies are in a form of continual, continuous change, similar to the course of a running river (he also applied it in his theory of consciousness as *Spatiotemporal Continuity* and *Continuity of Actual Existents*). It is just birth and death which are relative phenomena comprising of a constant passage from one state to another. However, according to the new discoveries in the brain sciences, it seems he was mistaken.

David Hume, the prominent British philosopher, believed that conscious perception is discontinuous—each perception arises independently. For him, perception is fundamentally fluid; it arises and then perishes. "Every distinct perception, which enters into the composition of the mind, is a distinct existence, and is different, and distinguishable, and separable from every other perception, either contemporary or successive" (David Hume, *A Treatise of Human Nature, 1739*). Puzzled with the continuity of identity (despite its discrete and independent essence), Hume expresses his idea about consciousness with the claim that a substantial unified *self* does not exist— it is discrete, atomic and linearly successive.

Years after, Immanuel Kant described that our knowledge of the objects constituting natural phenomena; our perceptual experiences and theoretical reasons in understanding them are completely structured in temporal frames. He demonstrated the ubiquity of time in the performance of cognitive reason. In a more concerned theme of today's scientific jargon, it can be paraphrased in this way that all of our actions are bound to a timing frame. They are all grounded in the form of time which constructs human cognitive experience. We perceive the world in somewhat fixed temporal parcels which are discrete and gappy.

As I mentioned earlier, from an introspection perspective, it seems that we picture the psychological time as a smooth flow. William James (1890/1950) is one of the pioneers of consciousness who grasps it as "sensibly continuous". He meant that the flow of time as we experience is not prominently interrupted by regular indicators. From James's viewpoint, if we take motor behavior as an instance, as well as in perception, timing appears to be continuous. In other words, when we pedaling a bicycle, or adjust to different musical tempos in dancing or playing an instrument, we are able to speed up or slowdown in it. Besides, what he describes the experience of time as a stream of consciousness is comprised of a series of moments in which each moment comes into existence and disappears only to be replaced by another. The thoughts and conscious reactions to events that encompass those moments are supposed as a continuous flow. But, if the description of the stream of consciousness, like that James proclaims is true, why do we have detours and breaks of thoughts during reverie or relaxed thinking? Besides, the flickering, perseverative, time-blurred images experienced in certain intoxications or severe migraines give credibility to the idea that consciousness is not river-like as it is perceived. It looks James's (stream of river) and Sartre's (a skier who slide down the sleek slope of snow) metaphors fail to answer these questions.

Is this basic claim of James concerning the continuous feature of consciousness correct? It appears that for some philosophers James's metaphor of river is problematic. Time flows like a river as James says), but it is difficult to realize how this writer can believe it psychologically conceivable for some philosophers who grieve from the vision that time is literally a river in

which they may drown. In other words, the fact that rivers have sources and estuaries whereas from some philosophers' viewpoint time has no beginning or end is indigestible. For we have no literal language of time, saying that time is a river confuses us with our literal river-language, also a literal language of time. For some, as the critique of the language of time, using these metaphors is not an appropriate way to explain the concepts. McLure says:

"Taking metaphors literally is only a fool's way of taking them seriously. The sane way involves rejecting the idea that because they are fictions they must be without hermeneutical significance (powerless to disclose reality), at best 'mere' and at worst treacherous. Considering the hermeneutical roles metaphor is now acknowledged to play in aesthetics, in the natural and human sciences, what is required in place of the outdated dogma of 'decorative and dangerous' metaphor (to which philosophers still resort wherever they think they can get away with it) is an exploration of the possibility of metaphorical truth and an understanding of how it is possible for us to break the rules of literal truth-getting.
"

Or, in line of this argument, Broad asserts that:

"(These temporal metaphors) give no help towards analysing or comprehending generic facts about time. A metaphor helps us to understand a fact only when it brings out an analogy with a fact of a different kind, which we already understand. When a generic fact can be described only by metaphors drawn from specific instances of itself it is a sign that the fact is unique and peculiar, like the fact of temporal succession and the change of events from futurity through presentness to pastness."

Also, E. Harris, in his classical article *Time and change (1957)* puts his objection on the metaphors of the time in this way. The punchline of his article is as follows:

"The flow of time', 'the course of time', 'the passage of time' are all spatial metaphors carrying the same implication—that of some mysterious kind of fluid that 'passes'. 'Passes what?', we may ask. The absurdity of this idea is emphasised when we speak of time passing slowly or quickly, for how can we measure the pace of time? The measure of speed can only be in terms of distance in space, covered in a certain period of time taken as a unit. Speed, therefore implies space as well as time, so that to talk of time as a movement (flow, passage or what you will) or of the pace at which it passes is not only an example of spatialization, but also a descent into an infinite regress, because a presumed movement of time requires another time in which to move. That ulterior time-series will then also be a 'passage', and the infinite regress is evident."

Broad's objection to temporal metaphor, on one hand sees them as the possibility of hermeneutically "helpful"— they would be revelatory of the nature of time— and on the other hand, he dismisses them in the ground of categorical mistake. Besides, these metaphors cannot augment our knowledge about the truth of the nature of time. It is like I say there is a cow in the field probably does not enhance our understanding of either cows or fields. There is also another objection on using metaphors in explaining time: when we say with a metaphoric language that 'time flows' or 'time moves', we assimilate time to motion due to lack of a language specific to time. Moreover, we perceive that motion as the fact of a body being at one place at an earlier time and at another place at a later time. In other words, we are not aware that time-motion spatializes time and accordingly it brings lots of logical problems for creating any fine-grained theory of time.

Furthermore, Galen Strawson, one of the contemporary analytical philosophers has proposed his objection on metaphor of river in this way (1997): Strawson considers our

conscious *thought*s as fragmented, full of detours and dead-ends. He does not see any stream as James sees in our consciousness. For him, as far as conscious thought and self-conscious awareness are concerned, our streams of consciousness contain numerous discontinuities and many sudden eruptions. He maintains:

"I think William James's famous metaphor of the stream of consciousness is inept. Human thought has very little natural phenomenological continuity or experiential flow—if mine is anything to go by. 'Our thought is fluctuating, uncertain, fleeting', as Hume said…It keeps slipping from mere consciousness into self-consciousness and out again (one can sit through a whole film without emerging into I-thinking self-consciousness). It is always shooting off, fuzzing, shorting out, spurting and stalling. William James described it as like a bird's life… an alternation of flights and perchings'…but even this recognition that thought is not a matter of even flow retains a strong notion of continuity…It fails to take adequate account of the fact that trains of thought are constantly broken by detours—by-blows—fissures—white noise. This is especially so when one is just sitting and thinking."

However, one may object to Strawson's idea that stream of consciousness has fissures. I could say that while my line of thought takes a detour, for example, while without noticing I pass from trying to write this sentence to indulging in a few moments of daydreaming, I do not find myself in total silence or darkness; the course of my thinking changes, my mental imagery changes, perhaps the focus of my attention changes, but everything else remains much the same. How is it possible that we become skeptic of such a reality of the stream of consciousness?

To answer this objection, firstly, I should mention that history of science is a cemetery of our false intuitions (e.g. Geocentric model of universe, also known as Ptolemaic system). Even in modern time, one in four people believes the sun orbits around the Earth and not the other way around. Interestingly, four in ten Americans refuse Darwin's theory of evolution. And even some Harvard graduates think the reason winter is colder than summer is that the Earth has moved away from the sun. From my personal experience, I also implemented an experimental philosophy of mind task on a group of young people in different parts of the world (*Europeans* versus *the Middle Easterners*) to know what their intuition reveals about deep philosophical inquiries (e.g. *Free Will and Determinism*). I realized that they had a relatively independent view to free will and determinism and surprisingly I could have manipulated their intuition very easily (Izadifar, 2017).

Aside from the fragility of our intuitions, additionally, there are bundles of scientific investigations tout that there is no such a thing as the stream of consciousness. It is just an illusion. Recent experiments in psychology and neuroscience have proposed that there are some total silence and darkness between our conscious perceptions. Michael Herzog and his colleagues (2016) in EPFL, have advocated a model of how the brain processes 'unconscious' information, suggesting that consciousness arises only in intervals up to 400 milliseconds, with no consciousness in between. They have also calculated those dark or silent gaps which is around 100 milliseconds. There is no such a thing as the river of consciousness, rather puddles of conscious perceptions. Should we still rely on our intuition? Perhaps, not.

Back to our historical review, Edmund Husserl the German philosopher in 19th century who established the school of phenomenology considers the same general experience as *inner time consciousness*, an element of his definition of the flow of time. Inner time consciousness is a capability to perceive both sequence and length of events, both of which contribute to the specious present. For Husserl, it was a puzzling issue that the human brain experiences

objects of the world in sequential order, while it also experiences time during viewing immobile or stationary objects. This idea is like James's (1890) stream of consciousness.

In line of supporting river-like argument of consciousness, Bergson believed that the moments of consciousness are not detached from each other— "there are no snapshots cut off from the rest; there is simply the continuous flow of our awareness". The continuous becoming of continuity has an organization which he calls "rational evolution". For Bergson consciousness is "an inner life that is ceaselessly changing an inner world in which one state of consciousness flows into the next". Bergson's moment never dies, his is "an idea without demise". To Bergson's and James's conjecture, time is precisely a continuous becoming which are never manifested as a discrete shape— time is not a series of droplets. There are also critics of Bergson's idea. The analytical philosopher Richard Gale (1962) objected Bergson of supporting to "the blob theory of time", which time is absolutely continuous. He maintains:

"I do not trust that Bergson meant to declare the absurd view that time as a whole is continuous in his sense, in which case it would not be conceivable to discriminate between earlier and later events".

It seems to me that the misunderstanding for Bergson's readers have is in reconciling the two claims he packs together under such labels as "qualitative multiplicity" and "heterogeneous continuity": according to these two terms, it is interpreted that (i) time is continuous, and (ii) that, nonetheless, time is heterogeneous. Consequently, we are able to find out succession/the discrimination of earlier time from later.

Among 19th century philosophers like Alfred Whitehead, the English philosopher and mathematician, time is comprised of discrete atomic durations, each categorized by internal indivisible characteristics. From his view, these durations are non-mathematically continuous. Each interval has an immediate successor and predecessor, from which it is detached by absolute discontinuity. Time is a course of "creative advance" in which reality becomes present in discontinuous spurts of creation. Whitehead believes that there exists a creative becoming of atomic continuities which he calls discrete durations or "droplets" of time. However, he adds that the process of that becoming happens with no continuity, no smooth move from one discrete form to the next.

It appears that theorizing about the nature of time and consciousness is not restricted to philosophers and brain scientists. Julian Barbour is a British physicist (influenced by Ernst Mach) who also theorized about this concept in his book *The end of time: The next revolution in physics (2001).* Barbour's popular quantum gravitational theory suggests that the universe is jam-packed with what we call *nows*. Each *now* looks like a point in spacetime. Metaphorically, it can be thought of as a snapshot including information such as the brain's memories at that instant moment. There is no connection between the snapshots. According to quantum wave reduction theory, each snapshot provides information about the occasion and memories of prior snapshots at that moment.

Besides, the analyses of Hameroff and Penrose (2003) is another example of hypothesizing on time and consciousness which roots in physics. It is somehow coherent with James's view of consciousness as "continuous flow". Their quantum-based consciousness claims that consciousness is the outcome of discrete physical events which is always present in nature as non-cognitive and proto-conscious event. For instance, the percept of a light flash is like a perceptual moment resulting from a quantum reduction. Furthermore, the brain smears the perceptual illusion of continuity to all those moments which is referred to as *flow*. For them, consciousness is the constructor of both a series and the flow of moment: they believe that "consciousness creates time".

Francis Crick and his colleague Christof Koch, from their first collaborative work in the 1980s, concentrated more closely on elementary visual perception and processes as a means for studying and understanding consciousness. Their investigations brought them to the idea— in a paper in 2003 called *A Framework for Consciousness*— that "conscious awareness (for vision) is a series of static snapshots, with motion 'painted' on them…[and] that perception occurs in discrete epochs." The idea of "snapshots" that Crick and Koch postulated was a requiem for James's and Bergson's theory of the riverlike consciousness— smooth and without interruption. However, the "snapshots" that they assume are not uniform, like the negative sheets of a photographic camera and the length of successive snapshots is not likely to be constant. In addition, the time duration of these snapshots for shape and color are not simultaneous. Although they show in their study that this "snapshotting" mechanism for visual sensory inputs is probably a simple and automatic procedure, they do not explain clearly how each percept that include a great number of visual features, all of which are bound together. Are the several snapshots "assembled" to achieve specious continuity, and how do they reach the level of consciousness?

Continuous and discrete models of consciousness are two different poles which change our standpoint towards our existence. Furthermore, it was a philosophical challenge for the past thinkers and it has also become a controversial research question for a vast majority of contemporary neuroscientists/psychologists in modern era. In recent years, we have witnessed a kind of favor of discrete form of conscious perception among modern researchers. They have come to this conclusion that continuous representation of conscious perception "cannot satisfactorily account for a large body of psychophysical data" (VanRullen and Koch, 2003).

5.3. Findings in Neuroscience and Psychology Supports Discrete Form of Conscious Perception

Our self is ever-present now and we do not experience a succession of nows. This present now is the only now there is. The now in which the body was born is the very same now in which these words are appearing. It is the only now there ever truly is. For this reason, our own being is said to be eternal.

—Rupert Spira

For some people, passing time is a perceptive achievement that offers continuity to discernment. But much of what we see is a rebuilding — by filling out what is considered incompletely. Incomplete vision produces a world that seems complete by the mechanism of the filling. What we perceive of the world is an illusion. We don't feel as detailed as it would seem. In other words, consciousness is not inherently continuous in time, even though it seems to be — its subjective face varies totally from the objective. It is a chain that every moment occurs and disappears with intermediate gaps. Moment by moment replacement in the arrow of time is perceived as an illusory continuous flow. The brain has the challenge to fill the gaps of these discrete experience of perceptual events. These discrete perceptual events can happen in different levels like sensory process, higher cognition, movement control, physiological data, speech and language, and cultural artefacts. But, one may ask whether these claims could be proven. How did we know that perception is formed in a

discrete form? Why is there the smoothness of our perception of reality versus the discreetness or discontinuity of its origins at the microscopic brain level? Many psychological and neuroscientific discoveries have hinted that much of the continuity of perception is an illusion because the brain exhibits perceptual completion from a discrete form.

I argue each organ and biological process in the body has become interconnected in a nesting time period in order to address these questions. All of them are on time: heartbeat, breath blowing, the digestive system cycle, liver action, sleep / awakening cycle rhythms, the brain. All of them have been fixed with a demonstration of time windows. In the upcoming paragraphs, I bring a wealthy of experimental findings from neuroscience and psychology in order to depict that mental activities, including cognitive activities, have discrete, separated functions— they are implemented in a somewhat assigned time frame. All these assigned time frames imply to this fact that conscious perception is gappy, discrete and bumpy and continuity is just a trick of our brain—an illusion.

By pondering in the microlevel of life, we find out that because of some neurophysiological or even survival necessity (evolutionary perspective), discrete timing of consciousness can serve better to the organism rather than a "sensibly continuous" time (Varshney *et al.,* 2006). Varshney suggests that neurons with discrete synaptic states may function better than neurons with continuous synaptic states. In another case, Abbott and his colleagues (2016) maintained that neurons converse with one another "almost exclusively through discrete action potentials".

Another reason for favoring discrete form of consciousness is noise tolerance (Chaudhuri and Fiete, 2016). There are many causes of noise in the brain such as sensory noise, cellular noise, motor noise. Due to these noises, information that is transported or transferred in continuous form unavoidably lose its quality and becomes corrupted. For example, let's take one of visual paths: information in human vision originates at the retina, then it is carried to the LGN via the optic nerve, before reaching the visual cortex. Applying Shannon's communications theory (Shannon, 1948) to communications in the brain, the presence of noise throughout such a transmission chain makes it implausible for the brain to retain continuous representation; noise will always accrue and accordingly corrupt the information, no matter how small the noise is.

Furthermore, Pöppel (1985) indicated with a neuroscientific method that how our perceptual constraints create a horizon of simultaneity— at which we distinguish audio and visual stimuli as occurring simultaneously, although the speed of sound and light are different in our physical world. We recognize audio signals as non-simultaneous when they are detached by an interval of about 6 milliseconds. If that splitting interval is shorter, we perceive audio signals as being simultaneous. Visual signals which are separated by an interval of 20 to 30 milliseconds are experienced as non-simultaneous. Below this threshold, they are perceived as simultaneous. In tactile impressions, the simultaneity threshold sets at approximately 10 milliseconds. According to these experiments, we perceive tactile, visual and audio events in a temporally restricted mode. According to Pöppel, this temporally restricted structure is perceived as one 'now' which are based on a clustered perception-related experiences constructed by our brains.

Evidence for discrete form of conscious perception also derives, for instance, from studies on *temporal order thresholds.* If subjects are requested to show the sequence of two sensory stimuli, temporal order thresholds in the domain of nearly 20 to 60 milliseconds are observed independent of the sensory modality (Hirsh and Sherrick, 1961; von Steinbüchel, 1995; Wittmann and Szelag, 2003; Fink and Neubauer, 2005). To measure auditory order thresholds, for instance two clicks are sent to subject's ears (both ears). If the stimuli are

presented simultaneously, the subject will blend the stimuli perceptually so that only one stimulus is heard. A delay of one stimulus results in hearing the two clicks separately in each ear if the interval between the two surpasses 2 to 3 milliseconds. Although the subject hears two clicks and might even distinguish they are no longer simultaneous, she will unable to specify their temporal order correctly. The delay between the two clicks must exceed approximately 20 to 60 milliseconds that a subject can indicate the correct sequence. Similar threshold domains have been observed both for the visual and the tactile modality in similar experimental situations.

Another proof comes from measurements of response latencies in pursuit and saccadic eye movements. When pursuit eye movements initiate, the latency of such eye movements has a strong tendency to be within 30 to 40 milliseconds intervals (Pöppel and Logothetis, 1986). Similar observations have been made on saccadic eye movements for human subjects (Fuchs, 1967; Ruhnau and Haase, 1993, Tanaka and Sengco, 1997).

In short-term memory investigations, Sternberg (1966), in an experiment which is known as Stenberg task (the experiment entails memorization of a positive set, a list of items such as numbers or words) discovered that the exhaustive scanning procedure through short term memory is disjointed, with approximate phase durations of 30 to 40 milliseconds.

There also exist some findings deriving from neurophysiological experiments which support the notion of discrete form of consciousness. Experiments on the brainstem auditory evoked potential prove that the midlatency response shows a clear oscillation in the first 100 milliseconds after stimulus onset (Galambos *et al.*, 1981; Gray *et al.,* 1989; Murthy and Fetz 1992; Podvigin and Pöppel, 1994).

Another example is apparent movement which is debated in terms of perceptual completion. For illustration, if one visual dot is tracked in time by another further away, they seem like separate dots, separate in time. But if they are close in distance and time, the brain connects the two events by making the one dot appear to move back and forth. In this illusion, known as beta movement (important for motion pictures), the brain fills the gap and perceives a movement sensation. A similar type of illusory perceptual connection is *the phi phenomenon* (seen at inter-stimulus intervals greater than those associated with beta) in which a sensation of motion is experienced between the images of consecutive stimuli without a change their spatial position (Steinman, 2001). Moreover, we can find this phenomenon also in *the Necker cub*e, which can be seen under two different perspectives, (there is atemporal gap between changing two perspectives) and a phoneme sequence like CU-BA-CU-BA, where one hears either CUBA or BACU (Radilova, Pöppel and Ilmberger*,* 1990).

Another piece of evidence about the discrete form of vision perception roots in what it is called in magician world *visual coin trick*. A magician makes the illusion of transferring a coin from one hand into the other. The magical experience of the trick happens when the closed fist of the second hand is opened and revealed to be empty. It seems according to some experiments (Beth and Ekroll, 2015), if the time interval between the false transfer and the opening of the fist increases it would be probable that the magical experience evoked by this kind of trick becomes remarkably weaker. From finding of this experiment, by increasing the temporal interval from 1 to 32 s, they observed an average reduction of the strength of the magical experience of 38%. But, how is it possible? Beth and Ekroll's analysis make the possibility that the brain has a limit to create a perceptual completion for the intervals between discrete process of vision creation and also in seeing a stationary object.

Another proof of intermittent consciousness happens when the general anesthetic by *Methohexital* or *Propofol* is employed (usually for short surgery). This procedure results in a retrograde amnesia. Upon awakening from surgery after 5-15 minutes long, some patients

report that what they recall is that they have being told that they will be given the drug and the next thing they recall is becoming awake and told that the surgical procedure is over. Furthermore, they were puzzled that "no time" elapsed between the two verbal events (Schwender *et al.,* 1995).

To cover some instances of discrete form of conscious perception in the higher levels, it is worth mentioning the color phi experience (Dimmick, 1920; Kovaćs and Julesz, 1992). In this phenomenon, the mixture of spacing and timing of the two images, a person who views the wheel report a feeling of motion in the space between the two points. The first point begins to seem to be moving, and then change color sharply in the middle of its illusory path.

In behavioral levels, for instance in decision making, a person who decides to buy a product in 1.99 Euros refuse to buy the same product if priced 1 cent higher (2.00 Euros). Such a sudden change in the brain's purchasing decision making cannot be modeled by means of a continuous representation despite broad attempts to do so (Basu, 1997). Besides, in cultural artifacts, such as hugging or shaking hand, a temporal window (around 3 seconds) has been observed (Schleidt *et al.,* 1987).

5.4. Brain Temporal Windows: What Do All These Experiments Confirm?

The domain of 30 milliseconds and in the domain of 3 seconds, is a necessary prerequisite for the construction of subjective continuity. Paradoxically, continuity is made possible by discontinuous information processing in the brain.

—Ernst Pöppel

From Von Baer speech in 1860 at the foundation of the Russian Entomological Society in St. Petersburg about subjective time (he came up with a concept of the moment, i.e. the longest possible time duration for an organism) till recent discoveries on discrete form of conscious perception, they all imply this message: underlying machinery of any organism's cognition modalities (sight, hearing, smell, taste and touch), there exists a temporal frame for processing (conscious perception is discrete).

Figure 12: *Beads on a thread metaphor.*

So, we are led to the view that consciousness itself occurs in short pulses, each of which is experienced as a whole, from which it is but a short step to the view that a stream of consciousness consists of a succession of such pulses (like beads on a thread), each a short-lived total experience— 'islands of nowness' (Pöppel, 1997). But, there are still unanswered, puzzling, and abrasive questions: How are these 'islands of nowness', or 'specious present' connected together? How does the brain make this bumpy road as a flattened highway? What is the underlying brain mechanism (if any) for creating this illusion of continuity? In my poetic term, what (where) is *the glue of our existence?*

6

THE GLUE OF EXISTENCE

Talk of the flow of time or the advance of consciousness is a dangerous metaphor that must not be taken literally.

—J. J. C. Smart

6.1. A Paradox: Discretely Continuous?

Zillions of electrical, chemical, and hormonal procedures happen in our brain every jiffy, but we experience everything as a smoothly running integrated whole. Likewise, during our life we experience changes each day, each minute, each second. Each year about 90% of our molecules and atoms in our body are changed in course of time (each minute 40 million cells die and are replaced), resulting in a new body about each year. But no one realizes this continuous and smooth change which in depth is gappy. More generally, we are constantly aware of phenomenal passage of time in which there is a continuous flow and recurrent renewal of content of our consciousness. This experience of passage is both continuous and homogeneous— my experience was not packaged into discrete components. We witness a continuous change and we are alert of every part of it. For instance, I move my hand slowly but smoothly across my field of vision. Moment by moment I see my hand at a different location; I also see my hand continuously moving. Not only is the movement continuous, but my experience of the movement is continuous.

Or, think about listening to a melody. It's not unfair to suggest that one by one we hear the sound of a melody. However, we normally say we listen to the whole melody. It is the same when a man hears a phrase. How do we hear phrases in an ongoing way? Furthermore, I have a sense of personal continuity in temporal directions (past and future), also depicted as an integration of the self in time, either as a *phenomenological continuity*—the experience of self-continuity that is felt through mental time travel or *narrative continuity*— arises from coherent life stories which maintains the continuity of my identity (Addis and Tippett, 2008).

How could this be, although our brain creates it in a discrete, gappy and fissionable procedure? Is there a link? A thread?

When we talk about a link, it is implied that there are some independent, far-away, and discrete packages that should be connected together so that the continuity happens. In this situation, the concept of continuity comes on top and the desire for finding the link initiates. The adventurous voyage for discovery of the underlying layers of continuity is commenced with these seemingly simple but deep questions: how is it possible those 'islands of nowness' (those discrete forms of conscious perception which I explained in the previous chapter) create such a smooth continuity of consciousness? How can we explain the temporal continuity of the flow of time consciousness? How self-continuity (or personal identity) is preserved? How can we face with the question of discrete identity and its continuous experience? What is the relation between the discrete nature of our mental experience and this unified and continuous whole? What is the connector? What is the thread of our continuity in time? If our conscious perception is discretely continuous, what is the glue of our existence?

It seems to me that the questions are much more problematic than they appear. Or, perhaps, you might object and see them as pseudo-questions. Nonetheless, if we take these fundamental questions as pseudo ones, we have radically evaded a deep inquiry and ignored a profound concept. However, for Cartesian dualists, the question of consciousness continuity in time could be solved easily. In fact, it is not even an inquiry. What connects before and after is time in the Cartesian concept of time. It involves a self-confidence that recalls "the day of yesterday" and connects "the day of tomorrow." The memory of the past in this context is limited to the present. The same applies to current future expectations. Furthermore, according to Cartesian dualism doctrine when we have the *'res cogitans'*—an immortal soul (mind) which does not follow the natural laws and functions independently from the brain, why should we bother ourselves with these questions? But, from a realist scientific view which is based on experimentation, this is not the answer.

Putting aside for the moment your personal objection to the questions and Cartesian dualism answers, I suppose that we should take the above-mentioned questions seriously: Firstly, experience of time movement is deeply rooted in the imagery of our society. In music, for instance, rhythm refers to an organized movement in time. The rhythmic energies of humans that root in their physiological and neural structure are interconnected with their capacity to create time in music. By a closer look, musical rhythm on its various levels, are not necessarily interrupted. Besides, the word stems from the Greek verb "to flow". Secondly, conscious perception as I mentioned in previous chapter takes place in discrete forms in time and there has to be a glue— a link to connect them all. A bond that gives a being the feeling of moving in a sleek vessel of time which all of us have strongly experienced. Thirdly, missing something is the best proof for its existence. In other words, we have lots of evidence that in some mental problems such as schizophrenia, patients suffer from being stuck in the moment and lose the experience of a smooth flow in time. So, it is the glue of our existence which should be understood from different angles.

With understanding the concept of consciousness glue, we are beginning a new story about our existence. It provides the key to opening a new pathway, a new line into the world of time, and a new method to demystify the causes of many mental disorders that our former scientists considered odd. But where does this interesting smooth torrent experience come from? Most of what we see is a reconstruction. The brain does so by filling the incompleteness of the perception that appears to be completing the world we observe. What we do not see is as detailed as it seems. It demonstrates that knowledge is not always

permanent in time. Consider this situation: I'm sitting as I write my dissertation at my lab on Goethestrasse in Munich, hearing the world go by in a flow-like manner. The windows are open and my attention goes and comes: my colleague in yellow dress goes by, my supervisor is talking on phone, the sun emerging from the clouds. But there exist also other sensations that appear to arise: the noise of a car engine, the scent of professor Pöppel's perfume as a breeze lights up into my consciousness. All these are events that catch my eye for a moment. I feel all of them in a smooth line in my consciousness. But the crucial questions are still there: although everything is shaped in discrete acts, insights and moments, how then do all of them hold together and extend in time? How, if there is only fleetingness of separate moments (the moments of a fundamentally special ones that seem to constitute our very existence— a collection of moments which make a flow of our being like a river), do we achieve continuity?

Putting those questions aside for now, what do I mean by continuity? The definition would seem self-evident, but let me clarify what continuity denotes here. In a broad sense, I mean continuity of consciousness in time not space. Besides, I do not plan to explore the continuity of time which physicists discuss in their jargon as a metaphysical concept. I empathically bring about this difference because I do not intend to confuse the readers with the concept of continuity of consciousness in space in an Aristotelian or Bergsonian notion. Aristotle's notion of continuity in space entails a procedure which is 'from something to something structure' as pertaining to physical motion repeating the continuity of space. Aristotle reduces the 'from…to' to a sum of spatial points. But he could not plausibly have maintained this to the qualitative change of an apple from green to red, or of a man from being happy to being sad. As you have noticed, neither of these transformations involve change of spatial position at all. Consequently, Aristotle's notion for continuity in this sense foreclosed. Bergson also with a narrow understanding of Aristotle, says that time, is space. This is the result of misleading apprehending Aristotle's continuity in the narrow sense of the wide-ranging magnitude of space. Additionally, with Bergson understanding of time, the Aristotelian concept of time was also misread, in so far as he from the beginning taken this dimensional character of time as spatial extension. You may consider, in an Einsteinian sense, space and time the same. It is also fine.

Moreover, I mean also the psychological continuity account of personal identity which what I call "no-time-gap-self". I believe that our self and its continuity in time—self-continuity— is fundamental to human life and it is necessary and significant condition so that one maintains the personal identity, a single concrete thing, an existent, a real entity. In fact, we are essentially creatures who perceive ourselves as subjects with a continuous self, persisting through time, extending our consciousness over time through our self-conceptions. Although our brain emerges our identity in a frozen, discrete, and divided sectors that are temporally scattered, the instants always flows continuously into the future and the past flows into the instant of the present smoothly. In the next chapter, I will go through the mysteries of our self-continuity in detail.

Thus, in overall, I intend to deal with two fundamental questions: Firstly, although conscious perception is discrete and temporally scattered either in our inside world (different neuronal oscillations and also diverse transduction time) or the world outside (different speed of light and sound), we perceive that we are moving in a sleek, continuous, and smooth tunnel of life and its events. Secondly, how "no-time-gap-self" is maintained? How can a typical person who, throughout a day or the entire life, has several thousand distinctive streams of consciousness still feel that she is the same person? How could it be that when we slide out from a sleep phase and fall off into a waking state, each morning we recognize ourselves in the mirror as 'I am that'? In fact it is central to adapt (survive) to the shape of self-continuity

that we are so subtle that we are frequently unaware of its psychological position. As the readers have noted, the questions are thoughtful, but our cognitive toolkit to decipher those questions seems feeble. However, we should not be that much disappointed. Before pondering about those fundamental questions of our existence, let me take the readers through desire for continuity that is seen in each corner of life. Whence this desire for continuity come from?

6.2. The Desire of Pursuing Continuity

For there is no joy in continuity, in the perpetual. We desire it only because the present is empty.

—Alan Watts

The emphasis of religions on resurrection or anastasis, belief in hell and heaven, and reincarnation imply our desire for continuity of life that persists after bodily death. The afterlife argues that the essential part of an individual's identity or the stream of consciousness continues after the death of the physical body. For example, the prospect of immortality on death and the continuity of life, eschatology and resurrection which are promoted by Abrahamic religions, inventing concepts such as soul or spirit and even ancient stories like the *Epic of Gilgamesh* are the best evidence of our thirst for continuity. Whether these crafted concepts by religions about the continuity of life after death is true or whether they have been shaped by religious figures in order to conceal their failed projects of creating a contented life for human in this world (you will die and everything will be fine!), the core of concept implies our desire for continuity.

Nonetheless, the persistence of continuity is not restricted to our level of existence. In evolution, for example, we apprehend that there is a peculiar, continuous evolutionary drive in outside world even in the lowest stages which tend to build up the organism from repeating patterns. Evolution is driven by the continuous, ongoing interplay of processes that generate micro-diversity within systems on a short-term scale and the selection is operated by different temporal and dynamic scales. History is still running and continuous. It seems continuity is in the essence of nature. It as an on-going process that is happening in real time, and which encompasses innovations and qualitative changes of diverse kinds. For example, consider DNA (deoxyribonucleic acid) with twin helices, for example. They transfer information for the building of living creatures and use their own organization's electrical charges to enhance the number of their mate. Chromosomes' function is similar to a tape recording device, which can replay a melody at any time. This is the technique which nature takes for the continuity of life. The combination of an organism thus recalls the interconnectedness of a sentence in speech and the interconnectedness of knots of a rug. They all weave and connect until the design is complete; all of them comprise cyclical spinning. Or, an additional example, in botany, the continuity of vascular system of the plants has been debated in various forms. It is believed that the molecular mechanisms ensuring vascular continuity within variable networks in a plant is still unknown (Berleth *et al.,* 2000). A pivotal role for auxins (a class of plant hormones which play a fundamental role in

coordination of many growth and behavioral courses in plant life cycles) for the continuity of vascular patterning of the plants has been demonstrated (Sachs, 1981).

The discussion of continuity is not restricted to natural sciences. In linguistics, for example, especially in discourse studies, how the continuity of sentence between interlocutors maintain is an enigma. It is often discussed that in order to connect information from separate sentences, an individual must be able to recollect both a representation of the discourse and a representation of the current sentence. The problem is not simply to remember the discourse but keeping the continuity. In fact, number of factors should play in construction of an integrated representation of discourse. How does the brain do it? To put it shortly, although the mechanism has been explained by the role of *referential continuity*— if a sentence refers to an entity that was presented in the instantaneously previous sentence, then it will be easy to integrate the information in the two sentences—the concept is still a puzzle (Ehrlich and Johnson-laird, 1982).

Interestingly, drive for continuity have been also reflected even in literary works such as T. S. Eliot, James Joyce, and Virginia Woolf. For instance, in *A Room of One's Own* Virginia Woolf expresses her admiration for the continuity of civilization (by the sense of passing on the traditions of the past) in which the individual authorial voice vibrates with clear tones of the past.

Furthermore, in historical and also anthropological studies, 'ritual continuity' is one of the topics which challenges the great mind of these fields (Bloch, 1977; Bradley, 1987). Ritual continuity concentrates on a puzzling question that how social interactions and religious practices have continued up to now, though coexistence of different kinds of rituals within the same society. There are abundant of assumptions: Eric Hobsbawm (1983) suggests 'Invented tradition' as a norm of behavior by repetition plays a leading role in continuity with the past. While Ian Morris (1986) suggests that invention of writing played as the glue of ritual continuity, some researchers like Zola (2019) analyzes the issue of 'collective symbols' in deciphering this mystery.

Another concern for the concept of continuity can be spotted in gerontology— the scientific analysis of old age, the course of ageing, and the particular problems of old people. It is discussed whether middle-aged and older adults struggle to preserve existing internal and external structures of their social life; and they prefer to achieve this objective by using strategies tied to their past experiences of themselves and their social world or whether continuity is an elusive concept. Among gerontologists, it is assumed that continuity is an outstanding adaptive strategy that is promoted by both individual preference and social approval (Hage, 1972; Atchley, 1989).

6.3. Discussions about the Continuity of Consciousness throughout the Course of History

Resurrection is the principal event of time. There is therefore no continuity in being. Time is discontinuous. One instant does not arise out of the other without interruption, by an ecstasy. The instant in its continuation—finds its death and resuscitates. Death and resurrection constitute time.

—Emmanuel Levinas

As a groundwork requirement for our life, there is unity in knowledge over time as well as at a time. A normal stream of consciousness is a continuous series of experiences which lasts for some hours, months, or years. It comprises an endless flow of existence from beginning to end — with an uninterrupted flow of experience stretching into our conscious lives. As a standard water stream does not always flow at the same rate; it is sometimes narrower, sometimes wider; some parts are turbulent, others almost motionless, so our stream of consciousness. Sometimes it slows to a crawl and sometimes speeds along. Consciousness is not a stationary but a flowing thing; it is always on the move. How are these consecutive islands of experiences related? What are they that make them fragments of the same stream? To gain a complete understanding of the unity and continuity of consciousness, I believe that we should take the plunge into the different thoughts about the stormy subtleties of the stream of consciousness throughout the course of history.

For Aristotle, *now*, is "the link of time". Besides, Heidegger takes this argument from Aristotle and echoes with approval that *now* has the essence of a transition. Heidegger adds that the *now* functions as a *Übergehende* (a crossing path). It is not a point next to another point, for which two points an intermediation would be required, rather it is in essence the transition. In other words, Heidegger sees continuity of consciousness lays in a non-fragmented *now*. For him, *now* is thus no part of time but time itself. He believes that because *now* is no part of time, a movement, in so far as it is calibrated by time, is also not fragmented. For him, *now* is transition, that is, it has a continuous transitional character. That's why we feel the continuity of consciousness in time. There should be a mechanism which creates this state of mind and glues every moment (*nows*) to another. But, how these 'nows' are connected, both remain wordless.

Interestingly, the philosophy of Descartes typically refers to such a concept of a discrete form with a number of "news," each one sandwiched among non-beings. He used it for the proof of life of God, arguing that since each instant is existentially independent of another, the conservation of the universe means its being generated continually at any instant (Meditatianes, III). He insisted on causal connections as the key role in the continuity of consciousness.

John Locke believed that consciousness plays as the glue that binds one's sense of self together into one's personal identity. He saw consciousness a mechanism to recognize our past experiences as belonging to us. He declared that continuity of consciousness should be assumed not as a simple persisting entity, whether material or immaterial, but as a continuously changing procedure of interrelated psychological and physical elements, later stages of which are properly related to earlier stages (Locke, 1694). Moreover, he thought that nature fundamentally does not make leaps and continuity is a given, quintessential spirit of existence. But, is it the whole story? Is it just a given? Perhaps, not.

In a historical pursuit of the glue of consciousness, David Hume believed that our ideas do not occur randomly. If they did, we would not be able to think consistently. Consequently, he proposed the principle of association in *Treatise of Human Nature* (1739–40): "There is a secret tie or union among particular ideas, which causes the mind to conjoin them more frequently together, and makes the one, upon its appearance, introduce the other and these associations follow three principles: resemblance, contiguity in time and place, and causation. But, what is the secret tie? He remains silent.

It has frequently been stated that Immanuel Kant brought the concept of time into the foreground of philosophy; that plentiful of our obsession with time stems from his work. From Kant's perspective which is represented in the Transcendental Aesthetic (one of the sections in Critique of Pure Reason), time is needed as an a priori representation. He carefully

and meticulously restricts the dimensions of time to the cognitive performance of the human understanding. Therefore, time as an as already present feature plays the role of gluing the discrete conscious perception. It is already there. He puts it in his book Critique of Pure Reason (1781) in this way:

"Indeed, simultaneity or succession would not fall under its own perception, if not the representation of time he used a priori basis. Only under this assumption that one can imagine that something exists at the same time as another (simultaneously) or in different times (successively)."

Among psychologists of mid-19th century, William James believed that consciousness is inherently continuous (it is like the stream of a river— smooth, sleek, and unbroken). However, in one of the chapters on the perception of time in *The Principles of Psychology* quotes an appealing thought of James Mill (the father of John Stuart Mill) as to what consciousness like if it were discontinuous (gappy). How the world might be seen if consciousness were like a string of beads of sensations and images, all disjointed. He states:

"We never could have any knowledge except that of the present instant. The moment each of our sensations ceased it would be gone forever; and we should be as if we had never been. . . . We should be wholly incapable of acquiring experience. . . . Even if our ideas were associated in trains, but only as they are in imagination, we should still be without the capacity of acquiring knowledge. One idea, upon this supposition, would follow another. But that would be all. Each of our successive states of consciousness, the moment it ceased, would be gone forever. Each of those momentary states would be our whole being."

It appears to me that James himself is doubtful whether existence would be truly possible under these situations: spark-like life moments which are isolated and they could not be connected to another moment with a total darkness. This situation is indeed like the condition of someone with Schizophrenia or amnesia. It looks like you have locked in the 'moment' which takes a few seconds in length. Oliver Sacks in *The Man Who Mistook His Wife for a Hat (2014)* describes his amnesic patient *Jimmie.* I suppose that it describes the situation better*:*

"He is…isolated in a single moment of being, with a moat or lacuna of forgetting all round him…. He is a man without a past (or future), stuck in a constantly changing, meaningless moment."

"Subjective time is constituted in absolute, timeless consciousness which is not an Object." This statement of Husserl began a controversial scope to the phenomenological understanding of time consciousness. Husserl solves the puzzle of continuous flow of consciousness or what he chose to call a "stream of lived experiences" by his contribution to a phenomenological experience of time. He points out that we do not, when experiencing an object in time, experience a series of "pure nows", or we would never capable of experiencing these series at all. Rather, the "living present" encompasses anticipations of additional experiences, which he calls "protentions", and echoes of experiences just slipping away, which he calls "retentions". "Retention" and "protention" are technical terms which Husserl uses in his *Lectures on the Phenomenology of Inner Time-Consciousness (1905).* From his viewpoint, the "now-phase" is only an abstract feature of a complicated structure of protentions fleeting into retentions. "Now" exists only in objective time.

Husserl advances this view by scrutinizing the experience of listening to a melody. When we are listening to a melody, the sound of each note depends on the adjacent notes. I do not hear merely a G, for example, but a note with a quality which would be distorted if it appeared in a different melody. Therefore, the future and past of the melody are tangled in the experience of any given note. In other words, when I am hearing a melody, according to "protention", the second note (say) which reaches to my ear is slipping away and the third is approaching (as Husserl believed, we always anticipate the "living present"). When I am listening to the fourth note, the third will be vanished, but the "retention" of note four that I have when I am listening to still exists. When note 5 arrives, I have "retentions" of notes 4, 3, 2, etc., and "protentions" of notes 5 and 6, etc. Consequently, continuity of consciousness is persisted through "retention" and "protention" procedure.

Despite Husserl's determinations in explaining the phenomenon, he never achieved in exhibiting the necessary relation between human being and temporality. Hence, he finalizes consciousness investigations in a traditional way, i.e., not as temporality but as an entity which either is in time or has time in it. It is worth noting that from Husserl's viewpoint the threads of time might mingle with each other. He simply takes it for granted that our experience of time is always serial. He believed that it is a hodgepodge of multiple serialities that frequently interrupt each other.

Among 20th century philosophers, the problem of continuity of consciousness is still a lively topic. For example, Gurwitsch (1966) also draws our attention to the importance of the bridges between phases of conscious life. His view is also instructive:

"The transition from one phase of conscious life to another never has the character of a sudden break; as though one on the one side there were a brusque end, on the other side a no less sudden beginning, and between these two brusque events a breach which had to be bridged. Heterogenous and different from each other as the contents might be which fill two consecutive phases of conscious life, there is, at least at the beginning of the second phase, a certain awareness, though vague, dim, and indistinct, of what has just gone."

For some theorists in consciousness studies in modern era like Gerald Edelman, the continuity of consciousness plays a vital role in the struggle for life because it is highly effective, highly adaptive. As Edelman calls it, "primary" consciousness allows the organism the interaction of perception and memory of present and past. In his book *Wider Than the Sky: The Phenomenal Gift of Consciousness (2004),* Edelman writes:

"Imagine an animal with primary consciousness in the jungle. It hears a low growling noise, and at the same time the wind shifts and the light begins to wane. It quickly runs away, to a safer location. A physicist might not be able to detect any necessary causal relation among these events. But to an animal with primary consciousness, just such a set of simultaneous events might have accompanied a previous experience, which included the appearance of a tiger. Consciousness allowed integration of the present scene with the animal's past history of conscious experience, and that integration has survival value whether a tiger is present or not."

From Edelman's viewpoint, we jump luckily to the secondary consciousness or human-specific consciousness with the advent of language. Consequently, by the instrument of communication human was able to obtain self-consciousness and explicit sense of the past and the future. As he believes, it is this which offers a thematic and continuity of self to the

consciousness of every individual. For him, consciousness is inherently continuous (as William James assumed). There is no gap between (Edelman, 1991/ the co-author).

The conundrum of consciousness continuity has also arisen in mystical thoughts, such as Sufism, Zen Buddhism, Vedanta Hinduism, Taoism, Christian mysticism, and possibly some practices of Jewish mysticism or Kabbalah that if everything is being created every moment, then how come we feel reality as continuous. As one of the enlightened teachers, a mystic and an authentic Sufi master, Rumi says that our illusion of continuity has to do with the pace and non-existence of the truth and the relative similarities of each moment. Our normal perception speed simulates a continuous reality. A tree does not seem every moment to be destroyed and rebuilt before our eyes. That is because the flickering takes place very quickly, and every gap in perception is filled with our memories of reality, which make us see it as continuity in time. Rumi explains this phase as below in one of his mystical poems:

"Illusion of continuity

The world is recreated with every breath,
Ignorant of this renewal we are,
caught up in day-to-day life.

Like a fresh stream,
moments of lifetime arise;
ignorant of this freshness,
body numbed,
we live the illusion of continuity.

Speed of creation fools us,
it's make-believe,
like twirling a lit torch…fire art created,
illusion of continuity…from a point of light."

Figure 13: *As Rumi says that the continuity of consciousness is like twirling a lit torch*

6.4. "Illusion of Continuity"

It doesn't make any difference how beautiful your guess is. It doesn't make any difference how smart you are.... If it disagrees with experiment, it's wrong.

—Richard Feynman

By placing it in the "distension of the mind" achieved by memory, Augustine rescued the temporal extension of our life. Surprisingly, Husserl too in his phenomenological approach takes "expand the soul" argument with the help of memory; only, with him, consciousness, which appears not to have been invented in Augustine's day, takes the place of the soul. But, can it be elucidated only by the role of the soul? And, we should ask both of them that what is the soul in the first place? It seems that their answers are not convincing and popped up from their religious minds, not on the basis of the empirical data (objective evidence). So, what about modern sciences like neuroscience and psychology? What do they present about this challenging and critical theme in our existence? It seems that recent advances in today's brain imaging technology in neuroscience, for example, has paved the road for us.

To the best of my knowledge, among psychologists and neuroscientists, most of their efforts have concentrated on spatial filling in our visual system and how visual system fills the gap between blind spots of retina (they have mostly overlooked the temporal filling of consciousness). They argue that although visual perception is discrete, the interval (gap) must be filled with something (Treisman, 1988; VanRullen and Koch, 2003; VanRullen *et al.,* 2007). And for some scientists like Niko Logothetis, vision is a window on consciousness which should be explored meticulously (1999). But, what is going on between snapshots of perception? How can we provide a schema to explain the experiential phenomena between these gaps? Maybe, answering to these questions assists us in decrypting the temporal lags in our conscious perception.

To put this topic more precisely, I should mention here that apart from the illusion of the continuity of consciousness, how we see the world with our eyes in a smooth and continuous form is also an illusion. The continuous perceived image filling the blind spot of the retina is clearly an illusory percept. The brain is not physically capable of recording information from that area. Although tracking an object with different eye movements (saccadic or pursuing) in the world is fabricated discretely (because of blind spot in retina), the image is felt uninterruptedly and does usually agree with the local physical setting and is predictive and efficient for the observer. Noë (2002) notes that because more potential information exists than the brain can obtain, it is much more efficient for the brain to recreate the visual world from less information. However, among theorists, it is debated as to whether there is actual filling in process and whether the brain simply ignores the blind spot and other regions (Ramachandran *et al.,* 1992; Blackmore, 2002; Dassonville, 2004; Hafed, 2002; Henderson *et al.,* 2002). But for J.J. Gibson (1975) the illusion of continuity of vision is something external. He argues that "A sequence of external stimuli or, at the very least, the rhythms of the observer's body, provide a flow of change, and it is this we perceive rather than a flow of time as such." He adds that "The observer perceives both what is altered and what remains unaltered in the environment".

In line of these arguments, Crick and Koch (1990) also have the same claim to explain the apparent continuity of visual consciousness. They suggest that "hysteresis," that is, a

persistence outlasting the stimulus causes we see our surrounding uninterrupted and smoothly. This belief seems very similar, in a way, to the "persistence of vision" concepts advanced in the nineteenth century by Hermann von Helmholtz in his *Treatise on Physiological Optics (1885).* To put it in another form, according to Crick and Koch's and also Helmholtz's hypothesis, the sense of visual continuity is the final product of the continuous overlapping of consecutive perceptual moments. The only difference between Crick and Koch's and Helmholtz's assertion is that Helmholtz supposed that this aftereffect occurs in the retina, but for Crick and Koch it arises in the binding of neurons in the cortex. Helmholtz maintains:

"All that is necessary is that the repetition of the impression shall be fast enough for the after-effect of one impression not to have died down perceptibly before the next one comes."

Koch also in another article (2004) proposed that perceptual completion or what I call vision gluing maybe "painted onto" the snapshots of visual perception— a kind of a superimposed percept or a quale, like that of music. Gruber and Block (2013) implemented some experiments that explain illusory perception between "snapshots" of stimuli and reached the same conclusion. Besides, Treisman's feature integration theory suggests that spatially focused attention is necessary bind the features of an object to the locus of focused attention (Treisman, 1988; Treisman and Sato, 1990; Treisman and Gelade, 1980).

Interestingly, the flow of visual consciousness does not function for some organisms. Evolutionary speaking, it is probable that no such flow of visual consciousness exists in amphibians. A frog, for example, expresses no active attention and no visual flow of events. It does not scan its environments or look for prey. The frog does not possess a visual world or visual consciousness as we experience it. It seems that it is only a spontaneous reaction to an insect-like object to dart out its tongue in response if one enters its visual field. By taking the frog's example, it might be that such a dynamic and continuous consciousness first evolved in reptiles around 300 million years ago (Sacks, 2004).

There is also an unusual neurological disorder that some patients experience 'snapshot visual frames' during attacks of migraine. Hence, they fail the sense of visual continuity and motion and see their surroundings as a flickering series of still pictures. These still pictures seem sharp and clear-cut, succeeding one another without overlap. Most of the time these patients report that the still pictures are somewhat blurred and they are shown in the way that they endure long enough that each 'frame' is visible when the next one is seen. This situation continues till three or four frames is exposed to the patients and the earlier ones are progressively faded. This cinematographic style of vision of these patients is comparable to films run too slowly. According to these patients' report, these attacks are rare, brief and not readily predicted. It is argued that forms of cinematographic vision in which some patients experienced (sharply separated stills or blurred snapshots in their vision) characterizes abnormalities of excitability in the neurons binding.

Such instantaneous, static visual frames may also occur in certain intoxications (especially with hallucinogens such as LSD). They report an unusual visual effect of stirring objects which leave a trailing stain with images repeating themselves, and afterimages are significantly elongated. Oliver Sacks, in his book *The river of consciousness (2017)* describes a situation in which one of his patients have interruptions in visual flow, stream of movement, action and even thoughts:

"I heard similar accounts in the late 1960s from some of my postencephalitic patients when they were "awakened," and especially overexcited, by taking the drug L-dopa. Some patients described cinematic vision; others described extraordinary "standstills," sometimes hours long, in "which visual flow was arrested—and even the stream of movement, of action, of thought itself. These standstills were especially severe with Hester Y. Once I was called to the ward because Mrs. Y. had started a bath, and there was now water overflowing in the bathroom. I found her standing completely motionless in the middle of the flood. She jumped when I touched her and asked, "What happened?" "You tell me," I answered. She said that she had started to run a bath for herself, and there was an inch of water in the tub…and then I touched her and she suddenly realized that the tub must have run over and caused a flood. She had been stuck, transfixed, at that perceptual moment when there was just an inch of water in the bath."

Likewise, Josef Zihl and his colleagues (1983) published a very fully described case of motion blindness: a woman who, resulting a stroke, was unable to perceive motion. The clinical reports maintain that the stroke injured highly specific areas of the visual cortex which is crucial for motion perception. This patient experienced "freeze frames" lasting several seconds, during which could only see a lengthy motionless image and be visually unaware of any movement around her, although her flow of thought and perception was regular. She might begin a chat with a friend standing in front of her but not be able to see her friend's lips moving or facial looks shifting. If the friend moves behind her, she continues to "see" him in front of her, even though his voice now comes from behind. She might see a car "frozen" in a significant distance away but when she tries to cross the road, that it was now almost upon her. She would see a "glacier," a frozen arc of coffee coming from the coffeemaker, but then comprehends that she had overfilled the cup and there was now a pool of coffee on the table.

In fact, continuity of vision in ordinary conditions gives no indication of the fundamental processes on which it functions. To understand its underlying mechanism, it should be decomposed experimentally or in neurological disorders, to show the components that compose it. The side effects such as flickering, perseverative, blurred images experienced in some intoxications or severe migraines gives backbone to the idea that consciousness is comprised of discrete moments. Besides, these evidences show that although such standstills of consciousness happen in some situations for a substantial period, automatic, nonconscious functions like maintenance of position or breathing, for example continues as earlier. This puzzling phenomenon brings this question whether the flow of consciousness works independently from the rest of the body system.

In ambiguous figures, like Necker cube, one is able to switch the perspective every few seconds. At the first look, one aspect of the figure projects, then to retreat, and another perspective is shown without effort of will. The viewer is able to continue back and forth in seeing the figure. Although there is no change in drawing itself, nor its retinal image (the changing process happens in cortical levels), there are two perceptual interpretations which is fueled by the conflict in consciousness. This perspective change is observed in all normal subjects and can be seen in brain imaging technologies its underlying neural mechanism. However, some Parkinsonian patients have problem during the perspective switching. They perceive the same unchanging view for minutes or hours at an instance. Necker cube experiment on some patients shows that the normal flow of consciousness could not only be split, broken into small, snapshot-like crumbs, but also suspended occasionally, for hours at a specific time span. These clinical experience casts doubt on James's cinematic vision that consciousness, in its very nature, is ever flowing. Besides, it is not just in perception, for example our visual experience, that we directly experience such a phenomenon. Thinking, for

instance, also involves a continuous sequence of occurrent thoughts and mental images, regardless of whether the content these thoughts is continuous or fragmented.

As I mentioned earlier, most of experimental data on the flow of consciousness has been concentered on the spatial filling in visual system. How consciousness flows in time is still an underrepresented topic (the glue of existence). However, there are some experiments which challenge this question. For example, the most recent effort in understanding the temporal process of filling the gap in consciousness comes from the study of Herzog and his colleagues (2016). They postulated a two-stage information processing model to explain the discrete perception and also consciousness. They implied that like other features, temporal features (such as duration) are coded as quantitative labels. When unconscious processing is accomplished, all features are simultaneously rendered conscious at discrete moments in time, sometimes even hundreds of milliseconds after stimuli were accessible. Their model defies prominent theories on the philosophy of mind, which believes that consciousness is a continuous stream. They also propose that the phenomenal experience of events has the appearance of continuity.

6.5. Visual and Auditory Imagery Flow of Music: An fMRI Single Case Study with A Composer and His Composition

Together with some colleagues I implemented an experiment about the flow of consciousness in time. We investigated auditory imagery as a roadmap in understanding the underlying brain mechanism behind the flow of consciousness. We implemented an fMRI experiment on a musician in two different forms of auditory imagery conditions: continuous and interrupted.

Understanding how inner thoughts, feelings or images are represented in the brain remains of course to be a challenge. One of these challenges is the investigation of human mental imagery. What if we take 'seeing with the mind's eye' or 'hearing with the mind's ear' as so-called mental imagery equal to perception? Aside from controversies over similarities in brain activation patterns between these two phenomena, many behaviorists believe that imagery has its own restrictions due to its obscureness and subjectivity (Watson, 1913; Pylyshyn 1973).

On the other side, cognitivists insist that we can find some clues from the "black box" as an index of what is going on inside the mind (Halpern and Zatorre, 1993; Griffiths, 2000). In search of imagery, we should also bear it in mind that imagery is not restricted to visual one. Auditory imagery is another form which has been investigated in recent years (Kraemer *et al.,* 2005; McGuire *et al.,* 1996; Halpern *et al.,* 1995). Apart from the personal experience of having auditory imagery, for instance by echoing a piece of music in our mind for hours, there are other fragments of evidence showing that some composers such as Beethoven who became deaf later composed outstanding music, presumably by his musical imagery. Therefore, what could be the brain mechanism of this phenomenon and how does the brain make the flow of this kind of imagery?

There are lots of studies in this realm which have been done with different techniques: MEG studies (Schürmann *et al.,* 2002), PET (Halpern and Zatorre, 1999; Zatorre *et al.,* 1996), and functional MRI (Halpern et al., 2004; Kraemer *et al.,* 2005; Yoo *et al.,* 2001), as well as behavioral measures with lesion (Zatorre and Halpern, 1993). The majority of these studies about auditory imagery pivots on one important principle that even in the absence of sound,

the neural activity in auditory cortex is present. Accordingly, although this claim is a very controversial topic, it seems that it is not far from reality that we equalize imagery of any kind to conscious perception. Yet, what it is missing from all of these experiments is the flow of the auditory imagery in time. If we took auditory imagery as a likely equal phenomenon to perception, what would happen in the brain pattern when we interrupt the internal music in different time sections? Do we have a different brain connectome with interruption of consciousness flow in time? Or, is it still working based on the default setting of the brain in auditory situation such as listening to a music? Here is the question: Does consciousness arise in a continuous or discrete form? Does the brain do it in a smooth, non-stop and continuous form or the perception is a sequence of discrete conscious instants?

In our experiment, we have tried to investigate the flow of auditory and visual imagery and the brain mechanism behind it with implementing a single case study using functional magnetic resonance imaging. We suppose that we can find some traces of brain mechanism in imagery in two different time modes. Thus, by doing a single case study as a roadmap in exploratory attempts of human brain understanding (Cohen, 2013) and a basis for raising new questions (Flyvbjerg, 2006), we found out some new patterns in brain mechanisms.

A 71-year-old German composer took part in the experiment after giving informed written consent. He had corrected-to-normal visual acuity, had no history of neurological disease. The composer is regularly involved in writing music for theatre. He was enthusiastic about being involved in the study and he understood the demands upon his time and effort. The study was approved by the ethical committee of Ludwig-Maximilian University of Munich, in agreement with the Declaration of Helsinki.

The composer was asked to compose a six-minute piece freely without prescribed limitations to genre or instrumentation. The music imagery was served as a stimulus for using in the fMRI experiment. The composer initially performed one resting-state session (lasting 7.5 minutes) during which he was instructed to keep his eyes close and was told not to think about anything in particular. After that, there were two experimental conditions using a block design paradigm, (each condition was separated by a pause of 5 minutes). The composer completed two experimental runs in the scanning session. In the first run, the composer was instructed to imagine himself composing the music piece as he did before, and to control the length of the piece by separating it into four parts (1.5 minutes for each part). Between two parts, he was required to pause for 30 seconds. No explicit feedback was given on the amount of time that had passed. The composer indicated the start and the end of each part by pressing a button with his right index finger. In the second run, no pause was inserted into the imagery of composing. The composer simply indicated the beginning and the end after he finished the imagery task.

Brain imaging data was obtained with a 3T MRI scanner with a standard head coil at the university hospital of LMU Munich. For BOLD signals, T2*-weighted EPI sequences were used (repetition time (TR) = 2500 ms; echo time (TE) = 30 ms; flip angle = 90°; acquisition matrix = 80×80; number of slices = 43; slice thickness = 3 mm, no gap between slices). In total, one run of 372 functional volumes was acquired for the subject. Structural data was acquired with a T1-weighted scan of each participant's brain anatomy (1 mm × 1 mm × 1 mm; 240 × 240 matrix, field-of view = 220 mm).

All neuroimaging data were preprocessed and analyzed using SPM12 (Statistical Parametric Mapping V12, http://www.fil.ion.ucl.ac.uk/spm). The functional scan volumes were subjected to spatial realignment to correct for head motion. In further preprocessing analysis, the mean functional image was co-registered to the anatomical image, normalized to the Montreal Neurological Institute (MNI) template provided in SPM12, and spatially smoothed to reduce

noise using a Gaussian kernel of 8 mm full width at half maximum. The task was modeled as a block design. Using a two-level procedure, we applied a general linear model (GLM) using predictors convoluted with a typical hemodynamic response function. To specify first-level statistics, the two conditions imaging with-pause and non-pause were compared to the resting-state condition (with-pause condition vs. resting-state condition, and non-pause condition vs. resting-state condition, respectively). We obtained parameter estimates for each condition, and then acquired statistical parametric maps of the t-statistic resulting from linear contrasts between the experimental conditions compared with their corresponding control conditions. Then contrast images were entered in a one-way repeated measure ANOVA for second-level analysis. For these t-tests, significant voxels initially passed a voxel-wise statistical threshold of $p \leq .001$, and a cluster-level threshold was obtained at the statistical significance level of $p < .01$.

On behavioral level, the composer can successfully estimate a time interval of 90s in the with-pause condition, when he was required to finish the imagery task non-continuously with three pauses to complete a 6-min long composition. The durations of the four parts were 80.79s, 80.90s, 85.28s and 129.34s, respectively. In the without-pause condition, the composer showed accurate temporal control - the duration was 6 minutes and 9 s, which is close to the predefined 6-min long piece.

In the analysis of the fMRI data, a widely distributed cortical network was found to be active during without-pause composition imagery. This network included the supramarginal gyrus and the postcentral gyrus, both in the left hemisphere. In the temporal cortex, the middle temporal gyrus and the superior temporal gyrus in the left hemisphere were activated. In addition, an activation of the left caudate nucleus was observed, which is usually considered part of the basal ganglia (Table 2, Figure 14a). The comparison of with-pause imagery vs. resting revealed the activation in the middle and inferior temporal gyrus of the left hemisphere. Moreover, there was significant activation of temporal pole in the left hemisphere (Table 2, Figure 14b). The Venn diagram illustrates the overlap between these two comparisons (Figure 15).

Table 2. *Location of brain regions that respond to comparison of with-pause condition vs. resting state, and non-pause condition vs. resting state*

Brain regions	MNI coordinates			Z scores	Number of voxels
	X	Y	z		
With-pause vs. Baseline					
L Middle Temporal Gyrus	-57	-10	-25	5.27	71
L Inferior Temporal Gyrus	-48	-13	-37	4.37	
L Temporal Pole	-54	5	-31	3.79	
Non-pause vs. Baseline					
L Middle Temporal Gyrus	-54	-10	-25	10.94	172
L Superior Temporal Gyrus	-60	-31	11	8.98	276
L Middle Temporal Gyrus	-60	-19	-7	7.87	48
L Caudate Nucleus	-24	-1	23	7.78	37
L Supramarginal Gyrus	-45	-40	35	7.78	258
L Postcentral Gyrus	-45	-22	35	7.64	

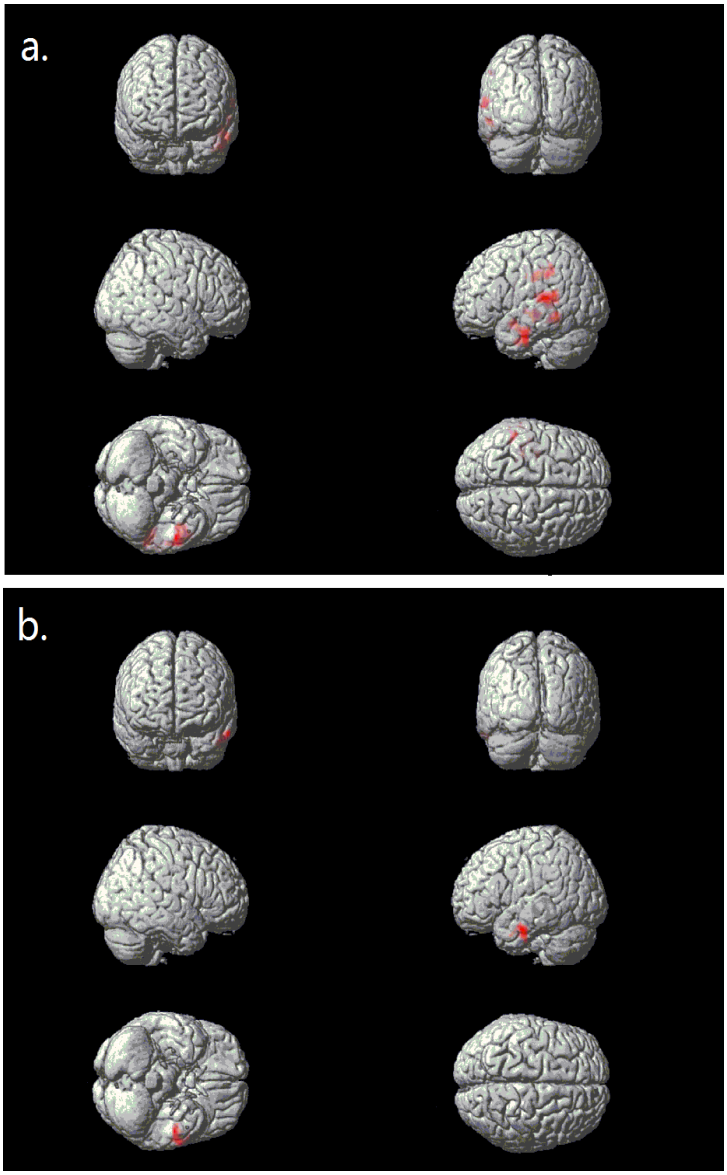


Figure 14a & 14b: *Statistical parametric mapping of processing composing without pause. Depicted activation differences are computed with t-statistics contrasting blood-oxygen-level-dependent signals when the composer made the symphony without stop compared to resting state (Fig.1a) and with pause compared to resting state (Fig.1b). Activations are cluster-level corrected with p (familywise error; FWE) < .05. The x, y, and z coordinates are normalized using a standard brain from the Montreal Neurological Institute and displayed in radiological convention.*

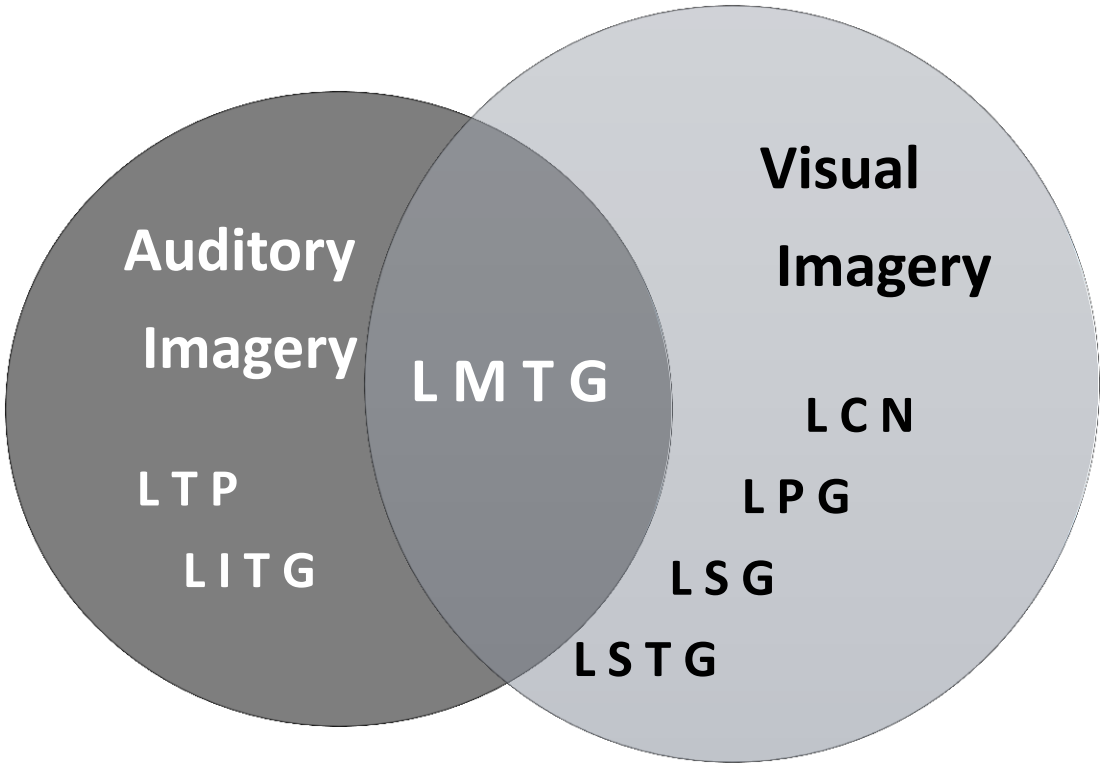


Figure 15: *Venn diagrams illustrating the overlap between with-pause condition vs, resting (left, auditory imagery) and without-pause vs. resting (right, visual imagery). Circle size is proportional to the size of the networks identified. Abbreviations indicate the brain regions where activities were found: LMTG, left middle temporal gyrus; LTP, left temporal pole; LITG, left inferior temporal gyrus; LCN, left caudate nucleus; LSG, left supramarginal gyrus; LSTG, left superior temporal gyrus.*

This experiment showed a unique result in auditory imagery and its relationship to neural correlates of consciousness. It was noticed that the brain uses a completely different mechanism while it is in a continuous form in comparison to when it encounters with pauses. We saw a significant stimulation in temporal gyrus in left hemisphere during two conditions. This idea shows that it could be the case of one of our research questions that this region fills the gap of the discrete form of consciousness, and it plays an important role in the illusion of continuity in imagery and perception modes. As our Venn diagram shows, there is a common activation pattern (left middle temporal gyrus) in two conditions (continuous and interrupted). Thus, we hypothesized that the activation of middle temporal gyrus as a common brain pattern in two continuous and interrupted forms periodically in the cortex could be the signature of the filling gap procedure in conscious perception.

Other findings on this region report that LMTG processing is a fundamental region in language semantic (Acheson and Hagoort, 2013). We can also deem that LMTG might be a denominator in the semantic glue of consciousness like the way it has in language semantic. This region works in a way that it connects one moment of living to another in a flat path like the chains of words which are connected in a sentence smoothly. In other fMRI reports, the role of middle temporal gyrus is supposed that this region is associated with processes such as envisioning distance, recognition of recognized faces (Gross, 1994). Some lesion studies on

this region designates that injuries of the posterior region of the middle temporal gyrus, in the left cerebral hemisphere, may cause alexia and agraphia for kanji characters (characters of Chinese origin used in Japanese writing) (Sakurai *et al.,* 2008). The left middle temporal gyrus is also activated during poem composition (Liu *et al.,* 2012). In object conceptual performance, the regional amplitude of low-frequency fluctuations and functionally relevant connectivity strengths of LMTG has reported that process largely conceptual/semantic brain network (Wei *et al*., 2*012*). Moreover, another study shows that theta-band oscillations in the middle temporal gyrus imitate novel word consolidation (Bakker-Marshall *et al.,* 2018). In schizophrenia, it is reported that auditory verbal hallucinations are related to cortical thinning in the left middle temporal gyrus of these patients. The results of this study indicate that an abnormally thin left MTG could be tangled with the pathogenesis of auditory verbal hallucinations (AVHs) in schizophrenia (Cui *et al.,* 2018). Furthermore, studies show that increased left inferior temporal gyrus was found in both low function autism and high function autism (Jia *et al.,* 2018).

On the basis of the functionality of LTMG in previous studies, it can perhaps be suggested on the basis of this experiment: The overlapping activation of this regions in two different conditions may play an important role in semantic gluing of consciousness. If we take the general capacities shared by language and music from cultural and evolutionary standpoint (Jakendoff, 2009), this experiment also indicates that there are cognitive similarities between how we compose music and language. The findings plus other experiments on poetry composition and the importance of this region in word eliciting suggest that LTMG functions the same in poetry composition, creating language and music composition. From a pathological viewpoint, findings on the lesion to this region have elicited problems in schizophrenia and autism. More explicitly, it seems if we take improvisation in music as a systematic auditory verbal hallucination which is shown in another form in schizophrenia, it could be considered that these two functions have the same brain patterns in origin.

It is yet to be determined whether the LTMG and its network are one of the hundred or maybe more causes of continuity of consciousness. There still exists many open questions whether there are other vital regions which can function drastically in these processes.

6.6. An Underrepresented Concept: The Temporal Problem of Continuity of Consciousness

The tendency has always been strong to believe that whatever received a name must be an entity or being, having an independent existence of its own. And if no entity answering to the name could be found, men did not for that reason suppose that none existed, but imagined that it was something peculiarly abstruse and mysterious.

—John Stuart Mill

Theoretically speaking, we can solve the problem of continuity if we consider these two problems seriously: *The binding problem of consciousness (in philosophical jargon) or multisensory integration/spatial binding (in psychological and neuroscientific jargon)* and what I call *the gluing problem of consciousness (temporal binding).* In other words, I believe that it would be necessary to study these two problems in order to decipher this unified, smooth, and continuous experience of our existence (Izadifar, submitted 2020).

So, what is the binding problem? The binding problem or what is known among cognitive scientists, psychologists, and neuroscientists as *multisensory integration* is the study of how information from the different sensory modalities (such as sight, sound, touch, smell, self-motion, and taste) which have been activated in different regions of the brain are integrated by the nervous system. To put it much precisely, phenomenologically speaking, we see ourselves as a unified 'self' in the center of the world which moves smoothly in time. However, it should be noted that the mechanism behind creating this existential unity is not integrated spatially. Different regions of the brain are distributed in building the edifice of 'conscious experience' or a special 'conscious perception' like seeing. In other words, the binding problem of consciousness pursues this question that how different brain regions are connected to create a unified 'self'.

Another puzzling issue which seems much more thought-provoking is temporal binding of consciousness. Consider this situation: when we are conscious, we have a sense of presence, and we can feel our own body spatially and temporally in the center of this world. We have the unity of this subjective reality by a phenomenological experience that I am 'one' person in 'one' world (Metzinger, 1995). Aside from how the brain constructs such an outstanding unity from spatial and mechanical means (the binding problem), lots of evidence approves that conscious perception occurs in discrete temporal frames (previous chapter). So, another problem arises which I call it the gluing problem. The gluing problem pursues this question that what happens in the brain that these discrete temporal frames of conscious perception or in my supervisor's terminology 'islands of nowness' are connected together in time and we feel like a continuous form of consciousness in a smooth form. In other words, conscious perception is discrete and temporally scattered both in our inside world (different neuronal oscillations and also diverse transduction time) and the world outside (different speed of light and sound), nevertheless, we perceive that we are moving in a sleek, continuous, and smooth tunnel of life and its events. How does the nervous system deal with these temporally scattered situations? In a much fine-grained analysis, for me, the answer lies in considering two important concepts which ultimately influence on the integrity of brain organization and our flow of consciousness in time: criticality of time and its relation to our brain and sensory information processing by the brain from the outside and inside world.

In a much more fine-grained categorization, according to Pöppel and his colleagues (1991) we encounter to five different kinds of binding:

1. Spatial binding of identical features within sensory qualities (e.g. for the establishment of connectedness in the visual modality); (Gray *et al.,* 1989; Engel *et al.,* 2001)

2. Object binding within one sensory modality for different qualities (such as surfaces with colors in the visual modality); (Treisman and Gelade, 1980; Navon, 1990; Wolfe *et al*., 1989).

3. Object binding for several modalities (such as the establishment of one object defined by optic and acoustic information); (Pöppel *et al.,* 1988; Ernst and Bülthoff, 2004; Wallace and Mamassian, 2004; Parise *et al.,* 2013)

4. Temporal binding for separate successive events (such as the establishment of a musical motive or visual motion); (Pöppel *et al*., 1991; Engel and Singer 2001; Holmes and Spence, 2005)

5. Semantic binding for contents of consciousness (such as the establishment of a continuity of thoughts that might be lost for instance in schizophrenia).

Turning back to the puzzle of continuity, in my opinion, the fact lies in the relation of the brain with time and time with the outside world. Let me clarify what I mean by these relationships. There is "interior time" inside our skull which concern the duration of neuronal activity with specific frequency ranges. In other words, I mean temporal ranges or circle durations of neural oscillations which occur according to different activities in the cortical levels of the brain. This comprises different frequencies oscillating from infraslow (0.0001–0.1 Hz) over slow (0.1–1 Hz), delta (1–4 Hz), and theta (5–8 Hz) to faster frequencies like alpha (8–12 Hz), beta (13–30HZ), and broadband gamma (30–240HZ) (Buzsáki, 2006; Buzsáki *et al.,* 2013; Northoff, 2017; Buzsáki, 2019). These different oscillations demonstrate different functions and, most likely, related to different underlying neurophysiological mechanisms that give rise a wide range of behavioral and functional activities (Buzsáki, 2006). Thus, these different frequencies with their particular cycle durations provides "windows of opportunity" (Schroeder and Lakatos, 2009; Lakatos *et al.,* 2013;) or "islands of nowness" (Pöppel, 1999) to provide a stage in order to an action is implemented rightly.

One also needs to consider the "exterior time" encompassing our body and the world. What do I mean by the "exterior time"? The Speed of sound is ~330 m/s and the speed of light is ~300,000,000 m/s. Our nervous system is bombarded constantly by these two signals which cause different transduction time in the brain. Transduction occurs when a sensory receptor switches a type of stimulus energy (e.g. photon, sound wave) into an electrical impulse (language of the brain) that can be understood by the brain. Therefore, due to difference in speed of light and sound, the brain encounters to the challenge of different transduction time. This biophysical fact primes to a logistic difficulty for the brain because information from different sensory channels should to be integrated. For instance, when you have a face-to-face talk with someone, the movements of the speaker's lips and what you hear occur simultaneously. According to the physical laws, this should not be happened. You should see first the movements of lips, then the voice. Nonetheless, the brain makes it simultaneous. However, there is a limit in synchronization of sound and light for the brain which is called *the horizon of simultaneity* (Pöppel, 1988, 1990). At a distance of approximately 10 meters, synchronization becomes problematic. The visual stimuli will be prior to that of auditory stimuli, consequently, we see first, then hearing happens. We have all experienced the lack of central availability of our conscious perception beyond the horizon of simultaneity in a rainy spring day by a marvelous thunderstorm.

Thus, the brain's "interior time" has to align to the "exterior time" in order to constitute "world-brain relation" (Northoff, 2017). Such a temporal alignment— timing on the ongoing activity is aligned to the timing of the stimulus— leads to a "world-brain relation", and it allows any organism to enjoy a smooth, uninterrupted, and well-balanced conscious experience in the world. Any imbalance of precise timing between "interior time" and "exterior time" leads to weird experiences. But, how does this function?

In summary, time and space are normal building blocks. While physics has studied time and space extensively, their importance for the neural activity of the brain and, even more importantly, the consciousness remains largely unknown. If time and space are most fundamental natural attributes and the brain itself is part of nature, consciousness can therefore be understood as a tempo-spatial phenomenon of the neural operation of the brain, in this context. Therefore, we should solve two problems: The binding problem (spatial

binding) and the gluing problem (temporal binding). I believe that overlooking one of these concepts will lag us behind understanding the conundrum of such a unique phenomenon. In a more fine-grained explanation, we should answer four questions:

1. How many brain regions are tangled in each distinct mental act?
2. How are these regions bound together?
3. Having understood how these regions are connected in a coherent form and which areas are involved, we should know how these distributed regions are glued to each other temporally?
4. How does the brain's "interior time" align to the "exterior time" in order to constitute "world-brain relation"?

Having said the importance of considering this theoretical frame, I know that we are far from reaching any straightforward answer or any rash result. However, as I repeated frequently, I do not intend to present any answer, but revitalizing a profound question. As Nikola Tesla (1934) reminds us that "The scientific man does not aim at an immediate result. He does not expect that his advanced ideas will be readily taken up. His work is like that of the planter—for the future. His duty is to lay the foundation for those who are to come, and point the way." I should also add here that our temptation in opening new horizons by our scientific tools and the different modes of thinking do not guarantee that every phenomenon is comprehensible to our brains. We should not forget who we are, indeed. We are a bunch of cells/neurons and a product of the evolutionary process who got out of hunter-gatherer communities— thanks to the phenomenon of surplus neurons and many other lucky causes— entered to an agriculture-based civilization and created philosophy, science and technology. We should be modest and know the limits of our knowledge, sensations, and understanding of our world. But these limitations should not stop us from conquering the mysteries of ourselves and the world we live in.

7

THE CONUNDRUM OF SELF-CONTINUITY

Daher ist die Aufgabe nicht nur, zu sehen, was noch keiner gesehen hat, als auch bei dem, was jeder sieht, zu denken, was noch keiner gedacht hat.

—Arthur Schopenhauer

7.1. Another Enigma: The Paradox of Personal Persistence and its Disrupted Nature

I am leafing through my photographs, facing at a slightly yellowish photo of a young child and saying to my friend: "that chap is me." What I say to my friend seems straightforward and uncomplicated at first shine. I am claiming that a person at one point in time— 'I' at present— and a person at some previous time—the child on the photograph—are the very same; the two of me are alike! But, what does make me identical with that kid?

Life, whatsoever it is, is a temporal flux. Everything is doomed to change often apparently beyond our awareness. My body appears totally different now, so does my mind. I have acquired new attitudes and new aspirations and relinquished a large number of old ones. Still, in an important sense, I am the same person. How is it possible that despite moment-to-moment changes in my appearance and mind, I am still feeling that I am that person? How can we tackle with this second by second gap and resurrection in our existence which leads to a foundation of wholeness and continuity of our *self*? How is continuity of self (collective set of our connected experiences in the vessel of time) that results in a feeling that one's life has purpose and meaning preserved? How can we explain the paradox of continual change and permanence, while having the experience of being as we are, and yet altered?

So far, I have tried to persuade readers with new brain science and psychological findings that our consciousness seems fragmentary, patchy like a pearl necklace (chapter 5). I hope that till now you have convinced that individuals create rich, unified identity that are not bound.

Furthermore, there exists a tension between the subjective seeming, and the objective state of affairs. In other words, the supposed clash between subjectively and objectively viewed entails that although, objectively, there are gaps in consciousness, subjectively, it does not appear that there are gaps. Besides, if we observe our mental lives in a course of time, we will realize that they are not totally logical, coherent, 'fluid', and consistently structured. Our thoughts jump from one topic to another, sometimes even unrelated ones. Our feelings strike us at peculiar moments 'out of the blue.' Our moods are changing oddly from time to time. Interestingly, according to circadian rhythm research (Pöppel, 1988), despite our diurnal fluctuations of all somatic and psychological functions (every 24-hour our biological and psychological identity changes), but we return to the same position (person).

On top of that, we lose consciousness now and then when we go through a non-REM phase of sleep, so that our mental life is far from 'continuous' in a temporal sense. But, strangely enough we feel that the contents of our thoughts even with their successive and jumpy nature belong to us and they are consistent with our psychological context. We do not surprise all the time by the patchiness of our beliefs, moods, emotions, sensations, etc. Thus, another puzzle turns shining: if the underlying foundation of stream of experience is composed of successive temporal atoms and there exists a seemingly unbridgeable gulf between our conscious perceptions, how self-continuity is preserved? How is it possible that despite the fact that our psychological lives are gappy and bumpy, our basic narrative is neither gappy nor bumpy?

Before scrutinizing those profound questions, let me clarify the concept of self and continuity and then I explain what I mean by self-continuity. So, we encounter to two words: *self* and *continuity*. At first, what is self? The self is a main constituent of consciousness. It can be designated as "backbone of our existence" (Sadeh and Karniol, 2012). From some thinker's view, the self (James, 1890 and George Herbert Mead, 1934), or psychosocial identity (Erikson, 1968) are comprised of two types. It can be reflectively established as having certain characteristics (James' Me or self-as-object), and it can be established in a pre-reflective sense of familiarity with one' s body, opinions and actions or the self as observer (James' I or self-as-subject), characterized as subjective sense of identity by Erikson (1968). For a consistent sense of self (James) or psychological identity (Erikson), both a synchronic integration of present features across different circumstances and a diachronic integration over time— self-continuity— are fundamental. In its diachronic phase, the self is the same over time, and it is felt as continuous.

Concept of *self* has been also proposed by neuroscientists in modern era. Most of studies shown the brain activation in the medial regions of cortex during self-related stimuli. The activation in these so-called cortical midline structures (CMS) has occurred across all functional realms such as verbal, spatial, emotional, and facial (Kelly *et al.,* 2002; Mitchell *et al.,* 2005; Zhu *et al.*, 2007; Feinberg *et al.,* 2010). Although plentiful studies have confirmed the role of (CMS) in creating the self, in my opinion, neural basis of the self is still obscure. Likewise, much more obscure is the brain (neuronal) mechanism in persisting the continuity of self.

Having said about the concept of self, what is continuity? What I mean about continuity is straightforward. I use the term 'continuity' in a very common and broad sense. It can be described as the absence of gaps which is said to be continuous. In other words, it is

composed of a very smooth, sleek, and uninterrupted sense. But, whence does this subjective sense of continued existence over time and space come from? What is its underlying neural configuration? Perhaps it is not very easy to answer.

Then, what is self-continuity? What are its advantages? Why is it vital for our existence? I suppose that *self-continuity*, or *diachronic self,* or *continuity of identity, or phenomenal continuity, or psychological continuity* (the terms that explain this concept are diverse and the literature is extremely confusing) is the combination of the many life threads or life-stories which are bound together in the tube of time. To put it in a different form, the sense of self-continuity refers to unique and persisting mechanism that outline who we are and condenses an individual's past and present self, and connects all to a self who he or she will become. As if there exists a backbone of the self that connects together one's person in the past, present, and projects future into a continuing sense of personal identity. Furthermore, these stories or threads are predisposed by cultural values or norms, and thus 'sense of self' is recreated between people in terms of one's connection with others which contribute to a sense of coherence, stability and continuity of self— the persistence of threads of meaning in life. However, serious illnesses such as schizophrenia disrupts these biographical threads of meaning and leads to the sense of identity problem in which people frequently say that their being in the world has altered dramatically.

So, why is self-continuity important for our existence? What are its advantages? To answer these questions, we should notice to the fact that we are inclined to persist until we cease— our most fundamental egoistic desires are to persevere. As we say, we want to live, a desire to continue. In my opinion, the sense of self-continuity is central in construing and cognitively forming our social world, controlling our emotional responses to that world, and instructing our behavior in light of both— our survival. Besides, for each of us, conscious of who we are, where we have come from, and sensation of an inner self continuity across time is fundamental to an individual well-being. We are often taken for granted the importance of self-continuity, but it can be challenged by life transitions such as entering adulthood, retirement, senility, emigration, and societal changes such as immigration, globalization, and in much unfortunate and extreme cases of mental illnesses such as schizophrenia.

Persistence of identity across time plays a leading role in survival and supports the fact that personal identity is deeply important. Research implies that the faculty to recognize the self is an evolutionary adaptation that is effortlessly persistent through automatic systems (Parfit, 1971; Hirsch, 1976; Wiggins, 1980; Damasio, 2011). In early childhood, individuals first understand "I am" and then understand "I am and I was (about age five)". Their past self and present selves become connected as they first begin to develop a personal timeline (Fivush, 2011). In other words, I suppose that any organism needs a continuous, chronological awareness of self simply to consolidate incoming information and execute daily behaviors. For example, one experiences a pleasure or pain, or intend an action, only if that pleasure or pain experienced and processed by the brain which belongs to that *self*, or that intention shaped, by one of the interconnected moments of consciousness that construct that person. As you have noticed, preserving a sense of self-continuity is initial to human activities. Yet, how do we do it?

There are wealthy of studies that indicate self-continuity has numerous positive consequences for psychological functioning and well-being (Bluck and Alea, 2008; Sani *et al.,* 2008). Perceiving a sense of self-continuity over time and across different situations can help individuals feel grounded in a social and cultural context, and accordingly manage their existential fears (Landau *et al.,* 2008). However, sometimes the procedure of self-continuity does not function as it is expected. For example, in the case of identity crisis, immigrants who

suffer from a disruption in identity continuity may experience the distance between them and their culture of origin. Thus, this disruption of self brings lots of psychological problems for them.

Furthermore, what distresses people in thinking that their personalities not change too much or too rapidly. Persons identify themselves with their beliefs, objectives, and character traits and feel that the steadiness of these is somehow vital to remaining the same person. Moreover, that psychological persistence is required to be caused by the constant existence of the same performing brain. Besides, the feeling of an individual as a continuing subject makes possible other psychological activities such as self-regarding emotions and self-interpretation. I suppose that it is these that are somewhat peculiar and distinguishes us from other conscious creatures.

To persuade ourselves of the importance of maintaining self-continuity, a simple *Gedankenexperiment* suffices. What if I awakened not recognizing I was me? Imagine that everything from daily activities and personal relationships, to future plans and aims would be totally disrupted. Or, for seconds look at the wall, then again change your look at somewhere else. The image changed but the content of conscious state not. The content is still steady, the same and continuous. You are still the person who looks. Changing perspective from the wall to somewhere else did not make you another person.

Having attended to the importance of self-continuity, you may wonder whether it is possible that this thread of identity is torn. Here are real examples of the fragmented, unprocessed moments of experience that exist when self-continuity no longer functions: schizophrenics are not entirely self-conscious, nor are they proficient of many of the sorts of experiences “normal” persons have. They do not yet have the cognitive ability to link different moments and features of experience into more multifaceted wholes. Or, consider the situation of a senile person. A senile person is incompetent to remember who and what he is, what he has made through his past life, what roles he has performed in the lives of others. He cannot get the story straight on who she is, and so lives in bewilderment about himself. These deficits make it difficult to form a coherent self-conception and self-continuity. Furthermore, people who are in persistent vegetative circumstances or with advanced dementia, certainly are not the same people they once were. Their family may well say of them ‘‘She is no longer there”.

Such accounts echo a painful understanding that the persons’ self-continuity (or identity) has been altered so severely as to make them almost strange as the persons they have known. By considering these cases we realize that self-continuity is necessary for maintaining personal identity because personal identity and self-continuity cannot fall apart: all the experiences in a single stream of consciousness are simultaneous. However, it is worth noting that sometimes people can suffer from amnesia, character change and illusory memories while maintaining their identity. There is a puzzle with the self-continuity in cases where a person suffers a loss of identity (due perhaps to a loss of all previous memories) while still enjoying an uninterrupted, smooth stream of consciousness.

Nonetheless, the situation of missing the thread of continuity is not as extreme as what I explained before. Particularly over long-life periods in the face of changes in life events such as immigration, divorce, and loss, self-continuity may be disturbed. Moreover, in daily life, small failures in self-continuity may also happen, as represented by a person claiming, “I’m just not myself today.” Or, in the face of more severe life challenges, saying that “I just don’t recognize who I am anymore.” In very late life, persons may also have the experience of looking at their photos and feeling that the photos they see “is not really me.” These examples prompt us that, although self-continuity is frequently taken for granted, when it is

disrupted (in different degrees) it leads to disorientation with some negative effects on individuals.

As the last words in closing this section, I should add that continuity of self is a dynamic and evolutionary concept. Like continuity in a stage play, continuity is also evolving over a lifetime of action and learning and battle and joyfulness and heartbreak. All of our experiences weave into the network of one's conception of oneself over time. Furthermore, this necessitates that the effects of past experiences and the anticipation of future ones mingle with one's present experience. It seems that according to this view each time a person experiences something, she consciously deliberates the past and future and decides how to comprehend the present on that basis.

Let me turn back to that old and good question, to that paradoxical state of our existence: How does our inherent fragmentary, patchy consciousness like pearls of necklace links together and we recognize ourselves every morning in the mirror? Many of great thinkers have tried to answer this question. However, their answers seem to me not convincing. I suppose the puzzle is far from our intellectual speculations. Before introducing my hypothesis, let me present a brief historical review and also new findings about this enigmatic question of our life.

7.2. The Same and The Same Enigma: Different Readings of How Self-Continuity Is Preserved

If you understand everything, you must be misinformed.

— Japanese Proverb

All being must be continuous, although its nature is discrete. Consciousness is not an exception in this realm, so is our identity. Our experiences originate in a perceptual and mental flow, although it is rather as a series of discrete or bounded instants. Even our own brain unceasingly changes its cells and activity configurations—the brain is highly plastic rather than stable. The continuous change of both psychological and physiological contents makes such a continuous view of identity rather improbable. Thus, if consciousness and also our body structure emerges in temporally scattered, gappy and discrete forms, how does the brain persevere our self-continuity (or continuity of identity)? Each morning when I wake up, how do I know I am 'me'? How do people construct a sense of self-continuity over days, weeks, and a lifetime? How is it possible that we gather together the events of our lives from beginning of childhood, and then integrate a lifetime of lived experiences into a biographical identity or a life story? How could it be that individuals are capable to actively work with the remembered actions of their lives to form, remodel, and reconstruct a life story over time?

Taken in a philosophical sense, how is it possible that we are one and the same individual throughout time even though both our cognitive and physiological qualities change over time? How does our '*self*' remain stable and continuing across time? To answer these questions, if I see the problem from a psychological and neuroscientific perspective, I realize that first and foremost fact lies in the temporal nature of identity. Furthermore, the identity is context-independent, from the temporary changes in our psychological contents as they are related

to changes in context. For instance, the identity which I preserve with my supervisor is completely different from the identity which I have with my girlfriend. However, I feel that I have a stable mental image of *self* across time, i.e., in a diachronic sense which amounts to "self-continuity", although it seems that identity remains somewhat an abstract concept.

The conundrum of self-continuity is a very old concept which has been deliberated in a broad spectrum of thinkers dating back to Aristotle's assertion that living things have 'a principle of change and staying unchanged due to divisibility of some temporally extended items' (cited in Wiggins, 2001). Afterwards, lots of scholars endeavored to untangle the complexities of this phenomenon. There exists a wealthy number of philosophers, psychologists, and neuroscientists who are on the top of the list. A very long list of philosophers in 20th century (Cassirer, 1923; von Hirsch, 1976; MacIntyre, 1977; Parfit, 1971; Perry, 1976; Rorty, 1976), and touchstone psychological theorists (Erikson, 1968; James, 1902; Piaget, 1968), and contemporary (Chandler *et al.,* 2003; Pöppel, 2010, Vignoles, 2018) have all tried to come to grasp the question of self-persistence in time as a significant feature of personal identity and also as a "universal in the human experience"(Levine and Thompson, 2004).

Let me begin with philosophers' standpoint about the question of self-continuity. Philosophers' arguments on the conundrum of self-continuity can be summarized into two main groups of answer: those that can be categorized as giving *physical criteria* and those as giving *psychological criteria.*

Among some philosophers who are in the camp of *physical criteria*, it is argued that generally self-continuity is tied to spatiotemporal bodily continuity and it is a necessary condition for personal identity (Williams, 1973; Shoemaker and Swinburne, 1984). Its basic form is as the following: person A in *t*, is the same with person B in t, if and only if there exists a spatiotemporal continuity of body X from t, to t and we identify A in t, with body X and B in t with body X. It means that we distinguish our friends and foes first and foremost by recalling their bodies (primarily their faces). For example, criminals are traced by looking for fingerprints or their DNA. In general, we take resemblance of body to represent resemblance of person.

But bodily change happens in human beings— over a period of around fifteen years every cell in the human body, except some segments of the brain such as the cortex, is replaced. Thus, me-twenty-years-ago has no biological bodily stuff in common with me-today. How can it be that self-continuity is bodily continuity if our bodies are constituted of completely different matter several times over in one lifetime? Moreover, as a counterargument, Shoemaker (1963) developed a *Gedankenexperiment* which indicated that the spatiotemporal continuity of the body is not necessary, but only the spatiotemporal continuity of the brain. Shoemaker depicts a situation as two persons A and B undergoing brain-transplants surgery and ending up with each other's brain. He concludes that although one of the brain-transplants seemingly is different from the other, the brain is the main denominator in preserving the person's continuity of identity. Thus, it appears that spatiotemporal continuity of the whole body is not necessary for personal identity, the spatiotemporal continuity of one fragment— the brain— could suffice. If I comprehend Shoemaker's thesis on continuity of self correctly, he supposes that each of us really exists and that we really endure through time by the brain.

Now, I present the formulation of the *psychological criterion* of self-continuity or what is called 'the standard view' or 'the dominant view'. John Locke (1694) is commonly considered as the founding father of this notion (Locke, 1694; Shoemaker 1970; Parfit 1971, 1984). This criterion is based on the concept of memory which was first proposed by Locke in the second

edition of *An Essay concerning Human Understanding* (1694). Locke and his successors argue in this way that between A today and B a year ago, there exist direct memory associations if A today can remember some experiences which B had a year, or ten years ago. For instance, I am now linked with myself yesterday and yesterday I was linked to myself of a day before and we can go so on into the past day by day. But, am I strongly linked with myself ten years ago? This is where psychological camps of self-continuity who are aficionados of the role of memory encounter to an impasse.

There are other objections to the role of memory in persisting self-continuity. As I mentioned earlier, they argue on the basis of that self-continuity involves experiencing an unbroken sense of self over time through a prearranged higher-order mental representation, such as a set of self-defining memories or a life story. It should be noted that memory, according to John Locke (1694), is the sole component of personal identity over time. However, Locke's criterion is discovered incomplete, but acceptable in spirit. Nowadays it is widely documented that memory alone is not enough. For example, the fact that I am able to have intentions at one time and transfer them to a later time necessitates having a kind of memory. But, no one except me can act on my intentions, irrespective of how far apart in time the intentions and the acts are. Besides, self-continuity is merely experiential state of affairs and do not depend on memories or thoughts. To illustrate, when we wake up from dreams, we sometimes cannot recall what we have experienced in the dream. But we are still assured that we have just experienced continuously a transition from the dream. This proposes that the experiences during the dream and the experiences after waking up states are fragments of the same phenomenally continuous stream of consciousness. Accordingly, self-continuity does not necessitate that one remembers the previous experience; and therefore, the role of memory is downgraded.

Later on, other views in philosophy expanded on the basis of that self-continuity over time is established by the continuity of a person's psychological dispositions. After John Locke's assumption on the role of memory in persisting self-continuity, other devotees of this kind of thought were developed which are called the neo-Lockeans such as Reid (1785) and Butler (1736) as pioneers. They believe there exist 'causal connections' in which mental states link together and create psychological continuation over time. But, what kinds of causal connections between these mental stages are there in order for them to establish continued personal existence? This question seems a really difficult one and, to the best of my knowledge, trying to answer it, they brought more confusions than clarifications.

Another philosophical doctrine (inspired from *psychological criterion*) maintains that self-continuity is defined as 'overlapping chains of strong connectedness' (Noonan, 1989). If chains of linked psychological states overlap temporally— the way rope fibers overlap spatially— and if together these chains establish one 'four-dimensional worm' of which every time slice is strongly linked to their direct predecessors and successors. To illustrate, when I recall something that I did yesterday, or where an intention I had yesterday persists and today gives rise to an action, temporal chains of strong connectedness has given rise to my self-continuity. To summarize, according to this view, psychological continuity is supposed to establish personal identity in a transitive relation: If A is continuous with B, and B is continuous with C, then A is continuous with C. In symbolic logic form it can be depicted as: $(A \rightarrow B) \wedge (B \rightarrow C) \therefore (A \rightarrow C)$.

There are also some speculations among psychologists who are predominantly concerned with foundations of self-continuity. They maintain that self-continuity can be persevered through different approaches. One camp which are called "essentialists" believe that people attain self-continuity by focusing on the qualities that endure over time and trivializing

changes. This approach is related to the belief that a person has an underlying and fixed essence. Self-continuity, resulting from stability of the self, correlates with the passage of time (Parfit, 1971; Lampinen *et al.,* 2004). To put it much precisely, a person feels greater self-continuity from yesterday to today, than from a year ago to today (Peetz and Wilson, 2013). This might be due to differences in the changes between short and long temporal frames, or a laypeople idea that there must be more changes in a longer time frame.

Another approach which is discussed among psychologists in constructing self-continuity is through the "narration" (Chandler *et al.,* 2003). The "narrativists" argue that individuals can create their sense of self-continuity by developing stories. Within the cosmos of narrative, we have access to various ways and standpoints to deal with existential challenges. Furthermore, every culture is a narrative culture, and every narrative culture gives us an extensive repertoire of genres, plot models, and storylines. Through narratives, we can make sense of fluctuations of life, link different experiences, and achieve meaning and consistency of the self (Becker *et al.,* 2018). This approach underlines the connectedness between things and experiences, rather than "to imagine the existence of anything enduring or immune to time" (Chandler *et al.,* 2003).

Others believe that there is interconnectedness mechanism between personality and cultural underpinnings of self-continuity. Some of researchers have addressed this question in a cross-sectional study in different cultures (Schmiedeck, 1979; Anderzén and Arnetz, 1999; Timotijevic and Breakwell, 2000; Becker *et al.,* 2017). They found that members of collectivistic cultures maintain self-continuity more on an awareness of stability and associative links to one's past, while members of individualistic cultures ground self-continuity more on stories or narratives. For example, migrants are encountered to the challenge of integration, the formation of a new identity, and the transition phase from 'native' to 'foreigner' in order to preserve their self-continuity in an efficient way. Besides, Erikson (1963) and later Dien (2000) realized that identity crises arise when people lose a sense of personal consistency and historical continuity, being incapable to experience themselves as the same person they were in the past. In another study, Chandler and Lalonde (1998) hypothesized that disruption to a culture's future or a radical breakdown from its past would pose consequences for the people. They discovered that Aboriginal bands who did not effectively preserve their cultural continuity had reported suicide rates of up to 800 times the national average.

There are some psychological assumptions which address the bases of self-continuity from a different approach. For instance, Landau and his colleagues (2018) considered the question of "how self-continuity is produced". They showed that the sense of self-continuity differs from younger and older adults, and it roots in the sense of sped up time in life. Older adults are more likely to group experiential moments or events under broader classifications, whereas younger adults are more likely to store experiential moments or events as unique classifications. When older adults look back in time, there exists only a small set of classifications to integrate (stronger self-continuity). However, when younger adults look back in time, there exists an entire set of moments or events to integrate (weaker self-continuity).

Additionally, among psychologists, some scholars argue for the role of *nostalgia* as the denominator for individuals' perceptions of self-continuity, such that "who they are now" is linked to their sense of "who they were in the past" (Davis, 1979; Sedikides *et al.,* 2008; Becker *et al.,* 2018). Furthermore, according to many studies, nostalgia alleviates the pains of loneliness through pictures of social support (Zhou *et al.,* 2008), impedes boredom by replacing lost meaning in life (Van Tilburg *et al.,* 2013) and relieves self-threat by rising self-positivity (Vess *et al.,* 2012). However, as a counterargument, another group believe that

nostalgia has rather venomous effects: this experience can leave the person stuck in the past, and thus can alienate her from present situations by limiting the apparent range of attractive chances (Iyer and Jetten, 2011). Despite the objections, to date, empirical study has provided consistent evidence for the role of nostalgia in preserving self-continuity. For instance, it has been indicated that people who were asked to recall nostalgic experiences report an amplified perception of continuity between their past and present selves compared with people who were requested to recollect ordinary experiences (Routledge *et al.,* 2012; Sedikides *et al.,* 2018).

Others believe that self-continuity can be founded on the basis of dimensions that are relevant to the self, such as roles and deeds, thoughts and beliefs, social relationships, group memberships, and culture (Bluck and Alea, 2008; Chandler and Proulx, 2008; Iyer *et al.,* 2008).

Among modern psychology researchers, it seems that the role of memory has been revitalized again from its philosophical roots. They have found that the self and memory work together in creating self-continuity. Since continuity of self relies deeply on episodic memory which is endlessly storing imagery, perceptual, and sensory information about one's ongoing experiences, they propose that memory is a key player and the self a more minor assistant in preserving chronological self-continuity (Bluck and Liao, 2013). Furthermore, a group of researchers in France and Australia (El Haj *et al.,* 2019) discovered the role of memories which support the self-continuity in Alzheimer's Disease. They have examined how persons with mild Alzheimer's disease (AD) reflect on continuity of their self (i.e., whether they are the same person they were before). They concluded that people with mild AD rely on their personal and meaningful memories to maintain a continuous sense of self or even to ponder on situations in which they are concerned about their self-continuity.

Moving from the macro-level to the micro-level, in the realm of cognitive neuroscience, the neuroimaging techniques has revealed the role of the medial prefrontal cortex (MPFC) as underlying integration of self-continuity. Di Domenico and his colleagues (2018) found a link between (MPFC) and self-continuity persistence. In their experiment, participants see some trait adjectives and then they should respond (yes/no) to whether each trait adjective explained their past self ("Five years ago, I was …"), their present self ("At present, I am …"), and their future self ("In five years, I will be …"), while MPFC activity was scrutinized. They observed a high activity in the MPFC when responding to trait adjectives that referred to their past and future self as contrasting to their present self, indicating that the (MPFC) processes temporally separated identities in a different mode and assist in constructing self-continuity.

Hypothesizing about this enigmatic phenomenon of our existence is numerous, but my space here is not. In fact, there are lots of conjectures and suppositions that you, I believe, become disoriented in the forest of words which these theorists have created. So, I endeavored to give a sketch (I did my best to be clear enough) of what is deliberated among philosophers, psychologists and neuroscientists. Till now, we have realized that self-continuity is required to represent both permanence and change in our existence simultaneously. Self-continuity does not mean the absence of change but encompasses a conceptual thread that is established against a backdrop of ceaseless change. In other words, self-continuity not only guarantees our rightful possession of our own past, but also works to link us to our own as yet unrealized future.

Furthermore, we have noticed that Identity or 'self' are dynamic process —fluidlike— although its underlying nature is patchy. We are always moving through the vessel of time which gives us the sense of meaning in life. It seems to me we are like sharks in the ocean of life in which our movement and continuity should be always preserved. Any failure to keep moving is just another way of dying (a shark will drown if it halts moving). But, what is the

glue? How is our self-continuity preserved although its undelaying mechanism is discrete? It seems that it is a paradox. It is a paradox whose hopefulness for resolution has generated a range of potential explanations so absurd and confusing, in my opinion, that remind me of Bertrand Russell's quote (1959), "This is one of those views which are so absurd that only very learned men could possibly adopt them".

7.3. A Hypothesis in Search of Evidence

The true method of discovery is like the flight of an aeroplane. It starts from the ground of particular observation; it makes a flight in the thin air of imaginative generalization; and it again lands for renewed observation rendered acute by rational interpretation.

— Alfred North Whitehead

Once I commenced writing the dissertation, I kindled the attitude that I do not know anything about the answer, but I dare to enquire (actually, the whole journey began by a question in an autumn evening some years ago). I put all my energy together focusing on this thoughtful question of our existence— how those patchy, discrete, and atomic islands of nowness are interconnected together and create our smooth subjective experience? In pursuing this question, I tried to keep myself aloof from any probable answer because I realized that it would be naive to find a hasty answer for such an overwhelming question. Therefore, like holding a jewelry between my hands, I focused on observing the dimensions of the question per se. I believe that it is the question which should be examined, especially in this case, not the answer, because in the question lies the answer, not outside of it. The question itself has a vitality of its own because it is a serious question, not merely an intellectual one. This situation reminds me of a quote from Richard Feynman who says that "I would rather have questions that can't be answered than answers that can't be questioned". Likewise, as Wittgenstein has proclaimed, the fact that a thing has only one name does not entail that it is only one thing. Or, according to a problem which raised by Aristotle, who claimed that every category has an essence. The question of self-continuity is in exactly the same situation. The question that I pursue has definitely an essence and it is comprised of tremendous beauty and depth like a jewel.

So, how should we face to this profound inquiry? Should we make it more complicated by philosophizing? Or, should we try to find a silly answer? Might it be the answer in the mathematicians' models of the brain who made the situation much more incomprehensible? Or, could it be hidden in psychologists' experiments in a lab? Or, neuroscientists' fMRI images of a certain brain's region activity? Perhaps not. To answer these questions, I suppose, we should not be hasty because we confront to a multidimensional wonder. Despite all the complications, should we be hopeless? I suppose that we should not. I see more lights than smoke. I mean that in every cloud of unknowns, there exists a silver lining.

Yet, the curiosity and thirst for finding an answer are the basic elements of our cognition. We inherently search for an answer in any questions of our inside and outside world. We do not stop feeling hungry. We assume that there is an answer for everything. We are born with

justification and interpretation of the reality. Therefore, in this regard, I assume that the question I am pursuing is not an exception. I know that the answer to such a question needs an endeavor of lifetime, but, there is always an answer if we keep going.

However, what I present here is not an answer to such a profound enquiry, but a raw speculation. It is a hypothesis for search of evidence and an opportunity to comprehend, analyze and explore the foundation of self-continuity. The need to search the underpinning mechanism of the stability and connectedness of our self-continuity and its underlying neuronal machinery is the aim I intend to pursue. Nevertheless, I am aware that the answer is not something that can be gained in a year or so, rather it is a lifetime determination.

My focus will be specifically on the mechanism preserving self-continuity as a backbone of our identity. The hypothesis that I present is rather eclectic because I feel like that I encounter to a multifaceted phenomenon. My endeavor was to avoid from falling into the trap of mononcausality as a disease of all humans, namely what is called *"monocausalitis"* (Bao and Pöppel, 2018). He believes that humans have the craving to explain everything in a monocausal way. We are always looking for one reason only. He put it very nicely in one of his short articles which was published in *Edge* series (2007) in this way:

"The philosophical sentence "nothing is without reason" (nihil est sine ratione) is usually misunderstood as "nothing is without one reason". Occam's razor, i.e. to look for the simplest solution of a problem is OK, as long as a solution is not too simple. We are apparently victims of our evolutionary heritage being satisfied only if one and only one cause for the solution of a problem is identified (or claimed)."

I have tried to avoid all of these traps in hypothesizing. However, we as homo sapiens (the thinker/wise creature as it means) are inevitable to search for the interpretations. Having equipped with these thoughts, in brief, the hypothesis that I suggest possesses the following two major principles:

1) The principle of reafference (von Holst and Mittelstaedt) or corollary discharge (Roger Sperry)

2) The principle of a time theory

In the forthcoming section, I plan to explain each principle as a framework for thinking about this deep concept of our being—the continuity of self.

7.4. A Compass for Future Directions

The ability to perceive or think differently is more important than the knowledge gained.

— David Bohm

Change is the law of nature, but for many survival and sociological reasons, we should maintain our identity in the passage of time. A person should be able to think that he or she is the same person now as he or she was a few moments ago. Giving a poetical example in the light of this case, in order to be able to say that an apple has changed from green to red, one must be able to indicate the red apple and tell him, "It is the same apple that it was green." But persistence is not restricted to short period and it also applies for long term situations (e.g., years.). Someone seems like the same person today as while he or she was younger years before. It is necessary that we persist our identity and self within a block of space-time and have never disappeared. This cognition of persistence appears to be inseparably associated to the phenomenon of time. The persistence and time seem are two sides of the same coin. We vehemently tend to preserve our identity in the arrow of past/present/future.

However, the concept of persistence is not restricted to our identity. There is so called *object persistence* in which a person incline to recognize an object as being the same despite an alteration in either its spatiotemporal situation or its structure. For instance, in the *classic tunnel effect* (a car going through a tunnel), when motion is hidden, perceptual continuity is retained by amodal completion. That is, the viewer has an experiential phenomenon in which the object that entered the tunnel did undeniably pass through and left as the same object. Furthermore, even if the color of the exiting car is slightly different from the original one, the viewer still insists cognitively that it is the same car. The impulsive tendency of persistence is so overwhelming that the observer thinks that somehow a minor modification within the tunnel may have occurred. There are lots of experiments have done and many of them concluded that object persistence happens because of the principle of spatiotemporal priority (Michotte, 1991; Flombaum and Scholl, 2006). Another experimental example of the object persistence is a golf ball changing colors as it moves across. Even if it turns into a strawberry just as it falls into the hole, the golfer still considers it to be the same ball (his or her ball) that for unexplained reasons changed drastically. The brain does not reflect the possibility that the ball vanished and was replaced by a strawberry (Gruber and Block, 2014).

Putting aside the concept of persistence for moment, in the previous chapters I argued that the relationship of time and self is a significant factor and that self-consciousness is inseparably associated with our precise time consciousness. However, somewhat a few authors have been exploring the phenomenology of altered time perception in patients suffering from mental disorders. While experiencing the world, we experience ourselves in the flow of world time. Though it looks trivial, it is a notable fact that experiencing reality is only possible through experiencing the “now”; the current state. Put it simply, our present state is a main factor between time and consciousness, which is determined by features like attention, motivation and mood. For this reason, it seems to me that time experienced by individuals suffering from mental disorder is of special interest for a phenomenological approach to the topic of time consciousness. For instance, during periods of severe schizophrenia or in depression, an uncoupling of the self from the world is often described by as a divergence between self-consciousness and the flowing in the “world” time. The result is an experienced detachment between self and the umwelt, between “inside” and “outside-world”, and consequently between individual and world time. The cause for this is hard to comprehend.

But, under normal circumstances, healthy subjects experience the world in a way that moments of conscious experience in “nowness” are kept flowing with outside world time. As I mentioned in chapter 3, on the basis of Husserlian analysis of “inner time consciousness”, our experience of any sort of activity has a definite temporal frame in which any moment of

experience contains a retentional reference to past moments of experience, a current openness to what is present, and a protentional anticipation of what is just about to occur. Everything is inserted in the flow of time which regulates our individual perception of the current world. Our perception of the world is only conceivable if a temporal horizon has been founded. Yet, how does this temporal horizon occur?

Consider this situation: when we make a movement, we expect that it occurs at a specific time and location in space. You scratch your hand, you expect to feel a sensation simultaneously on your hand. When the feeling is spatially and temporally matched as expected, your brain interprets the sensation as self-generated. If there is a mismatch, if the signals are spatially and temporally discordant with self-touch, you decree it as being done by another agent. So, how does this system function?

Back to my hypothesis, I mentioned that in order to preserve self-continuity, two major principles should be followed: *The principle of reafference* and *The principle of a time theory.* I assume that if these two principles function properly, the self-continuity is maintained. Firstly, what is the principle of reafference (or corollary discharge) and how does it function in preserving continuity? I should add here that because I explained the principle of reafference (or corollary discharge) in chapter 4, therefore, I do not go through introduction again. Nevertheless, I explain it schematically here.

In brief, the principle of reafference or corollary discharge is on the basis of three main factors: *anticipation*, *comparison* and *image storing*. As it is discussed, there is always a copy of the outside world in the CNS which works as what I call a *compass image* in order to be compared with the main goal in an anticipatory form. Let me say that this copy of the outside world (*compass image)* is preserved in *memory*. Now, there is information about the past in the memory which is useful only (according to the principle of reafference) to the extent that it allows the organism to *anticipate* what may happen in the future. I believe that memory did not evolve to allow us to recall about the past, tell our long-ago life stories and enjoy sharing it. The unique evolutionary function of memory is to allow organisms to predict what will occur, when it will occur, and how to best react when it does occur.

To put it much more simply of what I intend to say, I bring an example: in our daily activities of life, we draw on past experiences in order to imagine and simulate episodes that might occur in our personal futures. When we imagine different forms of tomorrow, for instance, a date or a trip, we project ourselves into the future based on what we recall from the past. Indeed, we use the information about the past to anticipate what may happen in the future. Or, consider this situation: when we plan, we expect that it occurs at a specific time and location in space. You plan to drink a glass of water, you expect to drink to quench your thirst. When the plan is spatially and temporally matched as expected (according to the principle of reafference, as you remember, matched with the copy), your brain interprets the sensation as self-generated. If there is a mismatch (with the copy), if the signals are spatially and temporally discordant with the plan, you declare it as being done by another agent.

So, how could the reafference principle be applicable in my hypothesis? I suppose that CNS not only does have a copy *(compass image)* of the outside world, also it has an inclusive image of the *self*— the identity of an individual. It seems to be an understanding that an internal image of the external environment of man exists, which involves him in the center. There is a consensus among pundits that every entity has one such structure, a coherent type of systemic internal representations, without which actions can hardly be organized in a coherent way. This copy of self *(or, inclusive image)* which is comprised of not more than hundred images of lifetime events are stored as an autobiographical record in our episodic memory. These hundred images also are activated when we time-travel to our personal past.

Meanwhile, my supervisor, Ernst Pöppel did an experiment (he mentioned this experiment in personal communication) several years ago with this research question: how many images in our mind are activated when we time-travel in our personal past? Several hundred people take part in this experiment from different age groups, different professions, and members of different cultures. Time travel experience of these people's past showed that everyone can only activate a few hundred images, although we may suppose that it may be more.

Having said about the *inclusive image* which is stored in CNS, our brain consonantly compares *(comparator mechanism)* this image with different contexts in the outside world in an anticipatory system in order to make the *self* as a functional unity in a socially and historically fabricated form (the brain always desires to categorize and compare). The brain, is not a passive recipient of sensory information from world outside. It is now thought that our brain works like an anticipatory machine and it actively predicts sensations (Picard and Friston, 2014). In other words, CNS constructs a model of the environment (outside world) and compares the *inclusive image* to this model. When this inclusive image matches with the context 'outside', thus matching occurs between the reality of consciousness (the subject) and a reality outside of consciousness (the outside context).

So, when the comparator mechanism functions efficiently, the self is able to instantiate wide range of behavioral and mental situations favored by and harmonious with the perceived interests of the context in which it is communicated. In a normal situation, when the image (copy of self) is in concert with the goals of outside world, we are not so aware of them. We continue our normal life. But, when the situation becomes turbulent, we know that something is wrong. Let me give an example: when I meet my professor in the lab, I should maintain a completely different self-continuity (identity) from when I meet my girlfriend in a bar. Thus, upon visiting my professor, the brain begins comparing the stored *inclusive image* of him with the external world (the image of him who sat in front of me) in an anticipatory mechanism. Then, my self-continuity functions properly because there is a match between what is seen in the extremal world and the stored inclusive image in the CNS. So far, so good. But, this is not the whole story.

Having mentioned the anticipatory mechanism of the brain, as a side remark, it is worth noting that our brain tends to disturb the arrow of time. In fact, our common sense perceives the arrow of time as *past-present-future.* But, new investigations on our understanding of the psychological time appears that the arrow is *future-present-past*. The brain anticipates the "now", and it asks always: "what is next?" (Pöppel, 2009). Remarkably, in this kind, the theory of time starts from the future (in analogy to Heidegger), from the conceptualization of "what is next?". Our brain is what I call a "significance detector device" (SDD) in a sense that it is able to find— within an enormous amount of noises in the outside world— a particular desire which seems "meaningful" or better to say satisfying in an anticipatory way. The brain—as a multisystem parallel processor— creates the anticipatory pattern or what I say *(SDD)* by interacting with different more or less independent "modules" in its scattered regions.

It appears to me that the strong intuitive persuasion of the continuity of self is sustained only by advantage of extremely efficient operation of this system. The integrity of our self-image disintegrates when the rhythms of the inner world no longer match the dynamics of the environment that we live. In other words, I suppose that any failure to such a mechanism leads to various kinds of internally and externally generated turbulences. For instance, if we take schizophrenia as a disorder of the self, then there should be a turbulence between the original copy of self and its comparator mechanism with the outside world. The lack of compatibility between the *inclusive image* and the outside world or an unbroken band

between the self and the other leads to a catastrophe. Or consider, for instance, the TOT (tip of tongue) situation. A TOT happens when there is a sense that a piece of information is known, but it is not available for conscious report. As you see, there is a conflict between inside and outside world. In other words, there is a piece of information that cannot be matched with the outside context of conversation. There are lots of these situations which should be observed.

It should be noted that I am not the only one who has applied the principle of reafference in order to explain the higher order functions of human. The model of reafference principle has been also employed in understanding of behavioral control and also modeling human behavior by others. For example, Tanida and Pöppel (2006) elucidate hierarchical model of operational anticipation windows in driving an automobile on the basis of the reafference principle and experimental results on temporal perception and cognitive control. Furthermore, Glimcher (2003) refers explicitly to the reafference principle to explain human's economic behavior and how it might be embedded within neuronal programs. In another case, Merker (2005) posits the principle of reafference into the center of his reasoning in his theory of consciousness. In much more interesting case, Lindner and his collaborators (2005) diagnosed in schizophrenic patients a high association between measures of oculomotor control and disorders of agency. In their experiment, they found out that the poorer the EK (efference copy) was represented during an oculomotor task, the higher were the problems in the expression of self-reference in such patients. Likewise, there lots of evidence for efference copy failure is strictly linked with hallucinations and delusions in both schizophrenia and bipolar patients (Feinberg, 1978; Blakemore, Wolpert, and Frith, 2002; Ford and Mathalon, 2005; Leube *et al.,* 2010).

Now, I should turn to the second principle of my hypothesis— *the principle of a time theory.* In the first place*,* why does my hypothesis need a time theory? Why do I emphasize on the importance of time in my hypothesis? I suppose that the answer lies in the fact that the structures of behavior in any organism tend to be predominantly temporal (I explained it in chapter 4 in width and breadth). Take a close look at motions such as walking, for instance. Or, consider the way we communicate with each other. Any temporal change in an utterance, though the sequence of phonemes may remain unchanged can create a different impression on the addressee. In all of our activities, temporal aspects are crystal clear. Surprisingly, psychologists and neuroscientists have demonstrated reluctance to infer the existence of such an important factor like time in an organisms' behavior.

In line of this argument, it is also critical for the brain to know not only where to place attention, but when. Timing is denominator to almost every behavior we involve in, from neural computation to driving a car to playing piano. Besides, Intuitionistically, knowing when something will occur helps us to concentrate resources at that anticipated point in time to enhance our behavior.

Furthermore, to the best of my knowledge, what the principle of reafference (also the corollary discharge) misses is availability of a theory of time or better to say precise real-time system. Although von Holst and Mittelstaedt (1950) talk about "*a certain temporal delay, which is stored into the neighboring ganglia",* I suppose that they do not elucidate what they exactly mean by that *delay* in the principle of reafference. They do not mention how much that temporal delay takes or any clue about a clear timing system. So, the reason why I emphasize on the importance of time in the principle of reafference lies in the fact that I believe that there should be a critical timing in this process. Let me give a concrete example: For example, perceiving something and saying, "Here's a pencil," involves conditions that relate to time. I mean that not only is the style present for us, that is to say genuinely

attached to our senses, but we must also realize that over time, be two days or only two seconds, we have maintained the identity of the style. If the pencil appears one moment, and the next one disappears, or if it becomes a desk and then a stack of books, we will not say "Here is a pencil." As Kant called "recognition synthesis in a term" one thing exists to us that means that over time we will find a unity in its presence, so that we will call it with a word and also maintain its very existence. It is a fact that time's reality is the basis of awareness. Differences in the temporal system therefore bring about a lot of problems for an organism, since our experience has a temporal character.

Therefore, here, I add a timing system to the principle of reafference in order to elucidate my hypotheses and accordingly the conundrum of self-continuity. As I mentioned earlier, according to the concept of the reafference principle, humans and other organisms as well build up an internal representation, a model of the universe, a schema, a cognitive map, or what I called *compass image* from the environment in which they have located. Our brain constantly checks the compass image with what we plan to do. That is, our brain relentlessly seeks in an anticipatory form a cognitively compatible relationship with the objective world by comparison. For instance, consider preparing a meal. We have decided for that activity and have assigned a certain amount of time. Naturally, such a decision may remain implicit or unconscious for us if it has become our regular daily behavior. We assign a goal and to successfully reach that, neural mechanism of behavioral control has been designed in a way that observes each of our activities in a serial order.

Furthermore, our brain constantly checks the internal goal (e.g. preparing a meal) with reaching the goal. I suppose that there is a precise timing between comparator mechanism and anticipation system. In other words, if the precise timing adjustment (or temporal integration) between comparator mechanism and anticipation system encounters difficulty, due to some changes or some illnesses, temporary imbalance occurs in the process. This internal atemporal disorganization causes a crisis. Consequently, in schizophrenic patients for example, the crisis effects on cognitive-emotional structure of the brain and imposes rebalancing. Lack of cognitively compatible relationship with outside world (disorganized precise timing in comparator and anticipatory mechanism) causes a while new self when a new time appears.

So, according to this hypothesis, there exists a precise timing system between comparator and anticipatory system which synchronizes all of the functions in preserving self-continuity. In my opinion, among many other factors, this precise timing system is a crucial feature and leading denominator with which self-continuity is flourished. To recap, to put it differently, there should be a temporal precision between CNS and peripheral world to grasp the outside world. I deem when this temporal precision becomes dysfunctional, many problems occur.

As a matter of fact, predicting events in time is intrinsic to our mental life, and plays a leading role in the temporal structure of consciousness. Indeed, I suppose that precise timing system of comparator and anticipatory system of the brain help to bridge isolated events together and to shape the sense of continuity (a semantic glue) that constitutes our subjective life. But, what could it be that precise timing system? What is the *temporal precision integration* with which all perceptions (not only enjoying our self-continuity) functions properly?

To answer this profound question, I should cite again one of my supervisor's discoveries in the last 50 years of his efforts in deciphering the mysteries of brain and its association to time. For me, the precise timing system may lie in what Ernst Pöppel calls 'the windows of presence' with duration of approximately 2-3 seconds. According to his theory, this 2-3 second time horizon provides a temporal stage on which any conscious activity is represented. So,

anticipatory system of the brain always asks "What is new in the world?" (Pöppel, 2009). From his view, this 2-3 second temporal window is a necessary (not sufficient) neuronal machinery for the creation of our identity, perception, emotions, memories, and thoughts.

Then, what could be the sufficient condition? I assume that the sufficient condition lies in the comparator and anticipatory mechanism of our brain on the basis of the principle of reafference. I believe that by merging Pöppel's time theory (2-3 second window) and the principle of reafference's comparator and anticipatory mechanism of the brain, we pave the road for decoding the underlying basis of our self-continuity. Nonetheless, one may ask whether I have any experimental evidence in hand to prove my claim. I personally do not have any yet. However, as the title of this section touts, my conjecture is only a platform for any future investigations. I hope it opens new horizons for me in decoding the underpinning neuronal mechanism of this conundrum of our existence.

Nevertheless, I believe that the best proof of the existence of something is when it is missing. There are lots of cases in healthy persons and illnesses that I believe they are due to an inefficiency in precise timing system of the brain (I mean between comparator and anticipatory mechanism in the CNS). In the following section, I present two cases (among many) which roots in a dysfunction of the precise timing system.

7.5. Two Cases

Each moment is a place you have never been.

— Mark Strand

Schizophrenia

Although the content of consciousness changes through time (e.g. personality changes), identity or let me say psychological continuity is still somehow the same. In fact, typical human self-continuity— the unity of consciousness over time— outspreads over a period of hours, from one episode of dreamless sleep to waking state. I wake up, eat breakfast, take a shower, get dressed, go to the institute, start my routine scientific life. I am conscious the whole time, and the experiences I have at each phase of my morning belong to a single stream of consciousness. However, this smooth subjective occurrence of self does not function for some people. In some patients, like schizophrenics, self-continuity is abruptly ceased. They experience a kind of divorce from reality with various behavioral disturbances such as hallucinations, delusions, and catatonia. In practice, the patient experiences a weird sense of losing the identity. It seems she is unable to preserve her identify of herself with the outside world. In other words, she loses contact with reality of the world.

There is also a large body of literature suggest that schizophrenics turn away from the outside world and become concerned with their own subjective state (Sass, 1992). By a closer look at some of the thought disorders of schizophrenia such as *derailment or tangentiality or knight's move thinking*—a failure to follow the social norms of conversation and not sticking to the overall theme of the discussion, or *pressure of speech*— a speeding-up of the flow of

speech, we notice that a metaphoric glue in the stream of consciousness is missing. Besides, there is an evidence indicates that their perception of the world differs qualitatively from that of a normal individual (Cutting, 1990); this, in consequence, leads to a deprivation in their gratitude of the outside world.

This is exactly the point which I put my finger on. Why do they lose their contact with the outside world? What does happen inside the brain of these patients that make them disconnected? Is it just a neurodegeneration in a region of the brain (such as Alzheimer) or lack of a special kind of neurotransmitter stuff percentage (such as Parkinson)? Or, is it only a genetic problem? Although lots of research institutes who investigate on the etiology of schizophrenia have concentrated on organic deficits, they were unable to reach a consensus why these people lose the thread of self.

But, for me, the answer to this enigmatic mental illness of human lies in an underrepresented concept among experts in this field— *time.* As I mentioned in the previous section and I would like to generalize it to schizophrenics, one of the causes of schizophrenia and depression is due to an inefficiency in precise timing system of the brain (I mean there happen a deficiency in temporal integration between comparator and anticipatory mechanism in the CNS). In my view the capacity to experience and actively interpret the environment instantly gets disrupted if this particular scheduling system (or temporal integration) gets affected. Simply stated, an altered consciousness of the inner time produces an altered consciousness of oneself. Therefore, in patients with these conditions, this change is noticeable. In particular, the time and self-perception of these patients are changed and they cannot cope with everyday life on the basis of personal records. Some patients report their daily condition to be "heavy," while passing time is considered to be some sort of "sticky."

The depressed person is trapped in circular thinking that unites him with the past. Those recurring thoughts become important, leading to a sense of stagnation and "disconnection" from the world today. Reduced optimism in depressed patients is another common symptom of shifting subjective temporalities. The future is impossible for them. For them, being in the future it is not possible to concentrate on targets. Sometimes, this results in a sense of culpability. It looks like it's terrible to build a new self. The person in question is now being decayed into "a prisoner of the past." The passing duration of the "outside world" is perceived as detached from the subjective time of the self-perception.

Even in some symptoms of schizophrenia like auditory hallucinations (patients may experience one or more fantasized voices, which may comment on their activities, or talk directly to them), the inefficiency in precise timing system of the brain between comparator and anticipatory mechanism can be tracked. But, what are the mechanisms involved in auditory hallucinations? The normal experience of "inner speech" offers a clue to this phenomenon. The capability to control one's behavior by means of self-directed speech progresses in early childhood, when children first talk out aloud to themselves before learning to internalize this process. This situation reaches a climax in adulthood in the capacity for mature, verbal thought. Even in adulthood, this kind of contemplation is accompanied by "subvocalization". Subvocalization consists of a covert activation of the speech muscles that can be identified by electromyography. It has been notorious for many years that auditory hallucinations are also accompanied by subvocalization (Gould, 1948). This observation has inevitably suggested to many researchers that auditory hallucinations occur when inner speech is mismatched to an external source (Feinberg, 1978; Blakemore, Wolpert, and Frith, 2000; Ford and Mathalon, 2004; Pynn and DeSouza, 2013). There are lots of these symptoms in schizophrenics which have the same impact on the victim. In most of these cases there is a

kind of misidentification— an alienated self-consciousness. In alienated self-consciousness, individuals experience their own conscious events as those of another agent and consequently fail to recognize their own thoughts or feelings as their own.

Here is exactly what I intend to highlight in which most of these theorists have not considered the importance of it: can it be the case that vocal hallucination is just a kind of subvocalization of the patient in which a temporal integration problem has caused it? Can we say that the patient hears his own voice, but due to a temporal integration problem between comparator and anticipatory mechanism of the brain, he feels that the voice is coming from somewhere else? Can we explain this phenomenon by my hypothesis? I say, yes.

For example, consider this: auditory hallucinators usually do not designate voices as qualitatively or phenomenally akin to ordinary audition or speech perception. Quite often they state that their experience of the voice is not dissimilar with their normal experience of their own inner speech. So, what leads them to judge that their experience of voices is a representation of another's speech? My proposal on the basis of the hypothesis I mentioned in the previous section is that the "verbal imagery" of these patients (all of us have a copy of our voice in our head) seems strange because due to dysfunction of precise timing of the brain between the main copy (the verbal imagery) and the new ideas which cannot be matched (in the comparator system) with the center of identity (inclusive image). Therefore, the patient experiences it as an alien source.

Schizophrenic patients lose the ability to preserve the self and perceive the current time as a critical phase of their disorder. Obliviousness in these patients ultimately paralyzes the self, which affects it to feel empty and unable to function. Schizophrenics, for example, sometimes assume that although they are aged, they are children or else forget about themselves in the past. It seems like they are forcibly disconnected and experience a loss of identity from their current life. The disconnection between identity and the current time, however, is not limited to such mental disorders. Soldiers returning from a shocking war have confusion about who they are. It is because the essence of the self is ready to be restored and linked to its time.

As we see from some of these patients' own accounts, schizophrenia triggers the sense of stopping time. This is not limited to common people, however. For example, Nietzsche was given an understanding of the timeless moment as a result of his illness according to Wilhelm Lange-Eichbaum (1946), a German psychiatrist. Nietzsche writes himself about the slowing down of his sense of time as a result of his emotions. Lange-Eichbaum also convinced Nietzsche to present symptoms of schizophrenia. However, Nietzsche may have increased this timelessness and insights into schizophrenia, helped him to write his 'Also sprach Zarathustra' and made him immortal.

In modern era, many researchers have been implemented lots of experimental studies on the timing inefficiency among these patients. In an experiment done by Butler and colleagues in 2008, they showed the inability of schizophrenics to appropriately coordinate events in time. Most of patients' dysfunctional coordination of events in time exhibited these problems: lengthened windows of simultaneity, shifted integration windows (Norton *et al.,* 2011), impaired two-pulse resolution (Schwartz and Winstead, 1982), reduced sensitivity in temporal contrast detection (Slaghuis, 1999; Chen *et al.,* 2000) and lowered thresholds in flicker-fusion detection (Slaghuis and Bishop, 2001).

Besides, if we take rhythmic music as time, we observe a very strange behavior among these patients: their movements become wooden, mechanical like a robot or doll, that it looks like they have lost their former naturalness and musicalness of movement. In other words, they become strangely 'unmusicked.' For an observer, they are like a still photo, a frozen frame which have stuck in a motionless moment— in a statelessness and timelessness

of irreality. We also see in Nietzsche's definitions (1883) regarding the pathology of music who suffered from schizophrenia as the 'degeneration of the sense of rhythm.'

Having observed schizophrenia from a deficiency in precise timing in the system, I suppose this illness, perhaps, is not based on a particular cause like what I have presented here. Instead, I think that schizophrenia arises from a number of increasing dysregulations, a destabilizing system which should be perceived from different stances (I already mentioned about the origin of this dysregulation from the concept of time perspective). I believe that by seeing schizophrenia as a precise timing dysregulation or a range of dysregulations of a complex system according the principle of reafference and the importance of temporal integration between the CNS and the outside world as a drastic factor, then its etiologies can come at many points, as can sources of healing. I hope that this perspective towards schizophrenia might also give a clue to a better healing system of this mysterious illness of human being.

I close this section with a main theme of a book from Louis Sass, *Madness and Modernism (1992).* In his book, he tries to relate schizophrenia to the artistic history of the last century— emphasizing that the 'descriptive' psychopathology of schizophrenia is still a lucrative and influential collection of information for all those interested in the mechanisms of the mind in 'normals', as well as for those attempting to understand the nature and cause of schizophrenia.

Déjà vu

We may not have access to the subjective experience of schizophrenic patients' disorder (not yet, maybe), but most of us (it is estimated to be experienced by at least two-thirds of the population with the frequency of less than ten times a year) have experienced a weird phenomenon called *Déjà vu*. Déjà vu is a French expression and it is literally translated as 'already seen.' It is the individual experience of familiarity combined with the awareness that this experience is false. We experience something in the situation which we think we have faced before. It is really a striking experience for all of us.

Déjà vu, from psychodynamics' and religious' views, is that it 'means' something, either metaphysical as a proof for reincarnation, or personal such as a sign of suppressed memories. In this respect, Freud (1939) believed that déjà vu was caused by re-experiencing concerns and events that had at one occasion been repressed. In another example, William James comes to grasp déjà vu as a variety of religious experience (1902). He defines it as: "a kind of insight into which I cannot help ascribing some metaphysical significance". Besides, he goes further and supposed that by scrutinizing mystical and vague experiences such as déjà vu, we might better understand human.

Over the course of history of science, déjà vu has seldom been observed as a serious scientific question. But, if we take it as a serious research enquiry, how is déjà vu as an enigmatic sensation explained from a physical perspective? What do scientists offer about the causes of this feeling? How is it produced in the human brain? There are lots of answers to this difficult-to-define feeling, indeed. Personally, I have checked many of published articles and books about déjà vu in our modern era. Most of the results suggest that— at its core— it is a memory error, and therefore it can be understood by concentrating on the memory system. For me, it is not a satisfactory explanation. It seems to me a *memory error* as the answer to this phenomenon is too general. There should be something else.

For instance, Daniel Schacter in his book *Seven sins of memory (2001)* considers déjà vu as a memory error but with a much more modesty that memory error is a 'misattribution' and it is not very well understood:

"Déjà vu occurs relatively infrequently, and there is still no convincing explanation of precisely what features of a present experience would produce the kinds of mistaken judgements that Arnaud theorized about ... we know little more about déjà vu today than we did back in the days of Arnaud over a century ago".

Nevertheless, putting the label of memory error on déjà vu is not a new idea. To the best of my knowledge, Titchener (1919) was one of the first scientists who categorized déjà vu as the 'feeling that all this as happened before' which endures for a few seconds in spite of the knowledge that the experience is novel" as an 'illusion of recognition and memory'.

Meanwhile, it is worth mentioning that déjà vu is also experienced by people with neurological and psychological disorders such as epilepsy and schizophrenia. It seems that there is an association between epileptic activity in the temporal lobe and illusions and experiences such as déjà vu. The explanations for the phenomenon among these patients are diverse. One of the camps believe that the network of regions activated in epileptic patients binds on a network of temporal regions incorporating the hippocampus and encompassing to the amygdala that are identified to be important for memory function becomes dysfunctional. However, the nature and extent of déjà vu in these populations are different: for hours in schizophrenia and minutes in temporal lobe epilepsy, compared to the typical duration of seconds for normal. But research about why schizophrenics have more frequent experience of déjà vu is scant.

Now, how can my hypothesis explain the puzzle of déjà vu? What is its applicability in deciphering déjà vu experience? What is the brain mechanism? How is it manifested in the brain? Before answering these questions, I begin with some statements from the masterminds of this realm: If déjà vu as Brown (2004) says is "pure metamemory experience unconnected with the empirical world" or on the basis of Neppe's definition (1983), it is "any subjectively inappropriate impression of a present experience with an undefined past", so, what is the cause of this disconnection or inappropriate impression from the world? What might happen that memory and the world outside cannot communicate to each other?

Furthermore, by a closer look, we notice that déjà vu is a confusion about the present moment which happen along with a disconnection from the world outside. Many people who have experienced it describe déjà vu as like being able to predict the future. It seems that it gives us a moment to get rid of now and fly to the future. There exists a kind of misperception of now which occurs. So, on the basis of déjà vu experience reports, according to my speculation, I suppose that it is a feeling of familiarity which is formed in response to a timing mismatch (or inefficiency in precise timing system of the brain) between the state of knowledge of self— *inclusive image* of the identity in memory, and the processing of the stimulus from the outside world. In other words, on the basis of my hypothesis, it is a kind of mismatch in precise timing system between comparator and anticipatory mechanism in the CNS in which the context and the self cannot coordinate with each other in the level of consciousness.

I am pretty aware that my solution could not be the ultimate answer to this enigma. Instead, it is only an endeavor to show that there is always a missing link which most of us ignore as a scientific scotoma and trap into a myopic scientific view. In this section, I have tried to convince that déjà vu is not merely a memory error and it might be explained by the principle

of reafference mechanisms and paying more attention to the significance of temporal integration of the brain. In fact, what I have explained here could be useful as a complementary factor for any theory about déjà vu in order to complete the neglected foundation— *time*.

8

THE UNFATHOMABLE SEA

Unfathomable Sea! whose waves are years,
Ocean of Time, whose waters of deep woe
Are brackish with the salt of human tears!
Thou shoreless flood, which in thy ebb and flow
Claspest the limits of mortality!

And sick of prey, yet howling on for more,
Vomitest thy wrecks on its inhospitable shore;
Treacherous in calm, and terrible in storm,
Who shall put forth on thee,
Unfathomable Sea?

—*Percy Bysshe Shelley*

A poem can paint a thousand pictures in our mind's eye. Shelley' poem which I have cited here includes an almost cruel irony as it talks of the terrifying nature of the sea and it would later occur Shelley himself loses his life whilst at sea. I suppose that Shelley probably eulogizes his murderer *(the sea)* in this poem. What this poem manages to do is depicting the sea as an outstanding entity. But, why does he mention the sea in this poetry? In fact, why wouldn't it be? It is an area that is still largely unexplored and contains many mysteries (scientists estimate that 95 percent of the oceans has remained unknown). It seems to me too the problem of brain time, our continuity in time and many other mysteries of the brain. It is such a profound concept which have puzzled us for centuries— it is still unknown and enigmatic. It is for me like an unfathomable sea!

But, why do I perceive it so profound and unattainable? As a quick answer, because I believe that ultimate knowledge is unreachable. How far we go there is the unlimited and if we admit that we are limited, the puzzle would be solved. We must first acknowledge that our ability to answer questions concerning to our existence is constrained by the nature of the inquiring organ. Although 100 billion brain cells within our skull is the most complex system in the known universe, we should be aware of this fact that it was not "devised" to understand the world any more than your computer was designed to write its own software. We should

understand fully our architecture and limitations before sticking to any answer. Besides, it appears that no matter how you attempt to decode a phenomenon, somebody will come up with another topic which we have to answer. And I do not comprehend how we could ever settle that.

However, I have an explanation in order for not falling into the pitfall of disappointment. As my professor Ernst Pöppel often utters, doing science is like a piece of art. We should see our scientific efforts like painting on a canvas or composing a piece of music. We should merge science and art as it was before. In fact, this separation of art and science is rather a modern occurrence— it did not exist in the past, and there is no reason why it should subsist in the future. Just as art is not simply of works of art but of a viewpoint, the artistic spirit, so should be science. In my opinion, science should not consist of only the accumulation of information but in the formation of different modes of perception. As David Bohm says, "The ability to perceive or think differently is more important than the knowledge gained".

Furthermore, I suppose that we as scientists have diverged from our main aim as natural ambassadors (my professor's motto). We should eventually move beyond self-interest efforts, political parties, pigment biases and nationalistic views (tribalism which has been so fashionable these days). Besides, we should try to see the world as it is, not as what we desire to see because when desire blooms, then corruption grows.

Likewise, we have crammed science with nonending philosophical discussions (none of them are looking for the truth) and restricted our horizons by mechanistic and even mathematical paradigms. I suppose both of them have founded in us a myopic understanding towards reality. Nowadays, many of brain scientists have an assumption that mathematical modelling of the brain is the only way to deal with the mysteries of this phenomenon. As far as I know, their view has been founded on the fact that because it has worked in some disciplines so well for a while, they have presumed that it has to be that way in understanding the brain.

At first glimpse, it seems difficult to unchain from our myopic views or what I call the scientific scotoma— a neglected insights and sticking to less perceptive explanations. However, in my opinion, it looks like that it is too cumbersome to overcome. In fact, what we need is openness to new ideas and dwindle our bias resistance. History of science is full of stories about the new ideas which were completely ignored. New ideas are extremely threatening for our scientific foundations, and henceforth is denied full access to the mind (Kuhn, 1962). To deal with that, we should create a mental space for new ideas to bring them into a stable consciousness, to give them conceptual shape, stocking them in mind even if they contradict our existing ideas, classifications, or even theories.

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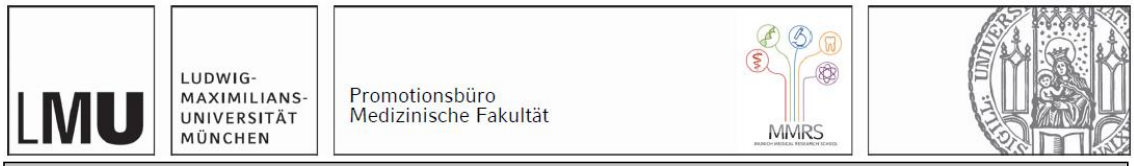
A C K N O W L E D G E M E N T

I owe many debts to those who have given me various kinds of support in my PhD period and also writing the dissertation. First and foremost, I will be eternally grateful to my supervisor professor Ernst Pöppel for all of his supports. He showed me what it takes not just to be a scientist and thinker, but what it means to be a good teacher, colleague and friend. Most importantly, he introduced me to a different way of thinking which is the main role of a teacher. Another important person that, on and off, has been with me throughout this voyage is my co-supervisor professor Yan Bao. Since the day I met her in Beijing and sometimes in Munich, I have been always promoted from her lucrative hints on my manuscripts and also the dissertation. Furthermore, I should mention financial support of Hanns-Seidel Stiftung without which this excursion was impossible to be fulfilled. I am extremely grateful for being given three years of uninterrupted stipend. Most importantly, I need to thank Mona. Without your constant support and encouragement, I would not have accomplished this. I am also thankful of your inspiring ideas which propelled me to the new realms of thought.

Affidavit



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I hereby declare, that the submitted thesis entitled:

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