Time is energy.
A hypothesis on the attentional origin of the conscious experience of time

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Abstract

The analysis of time is vitiated very often by circularity: several disciplines, such as philosophy, psychology, linguistics, and neurosciences, analyze time by using concepts or terms which already contain in themselves, or are based, on the experience and notion of time (as when, for example, time is defined as "duration", or when our ability to estimate durations is explained by resorting to the notion of an internal clock). Some detailed examples of circularity in the analysis of time are given here and examined. A way out of circularity is then given: it is represented by the proposal of Attentional Semantics (AS) of considering words and their meanings in terms of the aim they serve, and the means and processes developed and implemented in order to achieve that aim. According to AS, the main aim of words is that of indicating to, and eliciting in, the listener or reader a specific conscious experience: namely, the conscious experience referred to by their meanings. Words achieve their main aim by conveying the condensed instructions on the attentional operations one has to perform if one wants to consciously experience what is expressed through and by them. By describing the conscious experiences elicited by words in terms of the attentional operations that are responsible for the production of such conscious experiences, AS offers an a-linguistic counterpart to language, and therefore an effective way out of circularity. Following in Mach's footsteps (1890), but slightly revising his hypothesis, AS defines time-sensation as the perception of the effort made, or alternatively the nervous energy expended, by the organ of attention when performing a "temporal activity" (for instance, estimating duration), that is, when one's own attention is focused in a continuous and incremental way on the conscious product of the ("non-temporal") activity performed by means of another portion of one's attention. A semantic analysis of some of the meanings associated with the word "time" is then given.

Keywords: Circularity, Time, Linguistics, Psychology, Attentional Semantics, Consciousness, Attention

1. Circularity

One of the major problems when analyzing the meanings of words, and more generally when trying to scientifically explain and define objects and events, is how to avoid circularity. Circularity is that kind of fallacy that occurs when one uses in one's analysis, explanation or definition of an object or event concepts or notions that directly or indirectly derive from, are produced by, presuppose or imply the existence or experience of the object or event itself: in a word, when the *definiens* includes the *definiendum*.

Without doubt, the place in which circularity can be most frequently and easily found is dictionaries. Dictionaries give definitions of the meanings of words that are unlikely to escape circularity: as Wierzbicka (1996, p. 274) states, "circularity is a malady (in a more or less advanced form) to which virtually no conventional dictionary is immune". Dictionary definitions are sometimes circular in an open and evident way: *The American Heritage Dictionary of the English Language* (1973) defines "to think" as "to have a thought" and "thought" as "the act or process of thinking". Other times, dictionary definitions disguise circularity behind some intermediary definition. The *Longman Dictionary of the English Language* (1984), for example, defines "time", among other things, as "the measured or measurable *period* during which an action, process, or condition exists or continues; *duration*". However, the definitions the same dictionary gives of both "period" and "duration" are not independent of "time": "period" is defined as "the (interval of) *time* that elapses before a cyclic motion or phenomenon begins to repeat itself", and "duration" as "the *time* during which something exists or lasts" (italics are mine).

As we can see from these examples, dictionary definitions contain terms that directly or indirectly relate to the word that is being defined. This implies such a very tight circularity that it is legitimate to wonder how it is possible for anyone using dictionaries to understand the definitions they give without having a previous implicit or explicit knowledge of the meanings of at least some basic words. Indeed, if one does not possess such an implicit or explicit knowledge, one can hardly make any use of dictionary definitions: indeed, how could one understand a certain definition without knowing the meanings of the words composing the definition itself? Whoever wants to use dictionaries must already know, implicitly or explicitly, the meanings of at least some basic words.

It has to be noticed that it is precisely from this very condition that originates the usefulness of dictionaries, that is to say, the possibility they give of understanding the meanings of all the unknown words simply by combining the meanings of the known words. Therefore, if we consider dictionaries for this kind of practical and immediate usefulness, we must admit that the intrinsic circularity affecting their definitions is a lesser and acceptable sort of "malady". Likewise, from an epistemological point of view, circularity affecting dictionaries can be considered to be quite innocuous, since they neither add anything to, nor take anything from, what humankind already knew.

Circularity can also be found in scientific explanations and definitions. However, even if it is less frequent and evident than in dictionaries, circularity in scientific explanations is less acceptable, from an epistemological point of view, than circularity in dictionaries. This is because the main aim of science is that of improving and expanding humankind's knowledge by making us know what we

did not know before. Therefore, whenever a scientific explanation or definition contains circularity, science fails to achieve its main aim.

Moreover, circularity in scientific explanation, considering what kind of negative impact and perverse effect it can have on the development of knowledge in general, also appears to be far more dangerous and deceitful than circularity in dictionaries. As we shall see when dealing with research on time (and specifically with the internal-clock models), the way circularity in scientific explanation operates is so subtle as to divert scientists' attention from taking into due consideration the fundamental importance played by their mind in constructing and shaping the phenomena they are investigating. Although this fact usually may have little or no immediate consequence on the specific research they are carrying out in a given moment or context, it certainly has a big impact on the development of future research in general. In fact, it does not let them see that knowledge could be further deepened and widened if research was directed (or better, re-directed or re-oriented) toward a new level of analysis: the mental origin of the phenomena under investigation. This level of analysis is the one that tries to define and describe the way in which conscious and unconscious mental processes contribute to shape, give form to, and produce phenomena. By diverting scientists' attention from considering this level of analysis, circularity in scientific explanation blocks the development of research and the possibility of widening human knowledge.

Furthermore, by diverting scientists' attention from considering the mental level of analysis, circularity in scientific explanation contributes, in an endless and pernicious process, to perpetuate itself. Indeed, only by taking into due consideration, and becoming sufficiently aware of, the role played by conscious and unconscious mental processes in shaping and giving form to the objects and events as we perceive, see, conceive of, and more in general know and experience them to be, can scientists expect to be able to break and get out of circularity. Circularity is not only the cause of scientists' lack of awareness of the fundamental role played by the mind in building and shaping phenomena: it is also its product. Let us briefly see why such a lack of awareness favors circularity in scientific explanation.

As scientific research has extensively shown, human knowledge develops and is made possible thanks to processes such as perception, learning, reasoning, motor control, understanding and memorization, which for a great part rest on and are regulated by unconscious mental operations. Moreover, these processes, even when they initially occurred under the supervision of consciousness, progressively tend to become unconscious with practice. These processes allow us to equip ourselves with conceptual and physical tools that give us the possibility of successfully managing our life in this world. The whole set of these conceptual and physical tools constitutes what we call our knowledge, and comprises all the products of our mental, psychological and

physical abilities and faculties: products which range from the most complex ones, such as ideas, theories, words, procedures, instruments and machines, to the (only apparently) simplest ones, such as the results of perception. It has to be noticed that among our abilities and faculties, the mental ones play the most central and important role because of their governing, controlling, and coordinating functions. Due to the fact that, for a great part, our knowledge rests on and is made possible by the working of unconscious mental operations, unavoidably and to a great extent it assumes the character of being implicit. This implies that we know that we are able to do things (by "to do things", I mean generally the capacity to exercise one's mental, psychological and physical abilities and faculties: acting, moving, thinking, conceiving of, perceiving, etc.), but that sometimes we do not know how we do them, and what it is that allows us to do them: that is, we are not conscious of the processes and mechanisms that allow us to do them. We all know that we can add three to two and get five, but we are not conscious of the processes that allow us to do so. Therefore, when we want to explain our abilities and the basis of our knowledge, we are often led to speak of "intuition", "creativity", "instinct", "disposition", and so on. Not always are we aware of the mental mechanisms that gave and currently continue to give origin to and sustain our knowledge, and very often, even though we were initially conscious of how we learnt to do certain things, we soon forget the operations we did in order to learn those abilities. We are able to walk and tell the time, but not all of us can remember the original sensations we had, and how we reacted to them, when first performing those activities. It is this very lack or loss of awareness that made Saint Augustine say: "What, then, is time? If no one asks of me, I know; if I wish to explain to him who asks, I know not". An almost unavoidable consequence of this loss or lack of awareness is the fact that when we are asked to explain the basis of our knowledge, where it comes from, how it formed, and so on, we are led to look for the answer not so much where our knowledge actually originates, that is, the set of our abilities and faculties, of which the mental ones represent the most fundamental and central ones, but in some other places (typically, in a "world" conceived of as an entity completely independent of our mental, psychological and physical activity, a *prius* given to us in a pre-constituted and inalterable way). What is more, however, is that we do not realize that these other places are themselves nothing else than a product of our abilities, of the conceptual and physical tools with which we equipped ourselves, and that these places are full of the products of such abilities. Therefore, the lack of awareness makes us sometimes explain our conceptual and physical tools and their origin by resorting to concepts, ideas, objects, etc. that result from these very same conceptual and physical tools: circularity is thus brought about by the lack of awareness.

2. Circularity in the studies of time

Generally speaking, studies of time – regardless of the specific discipline in which they are carried out - lend themselves to being flawed by circularity. This is probably due to the twofold, impalpable and contradictory aspect of time. On the one hand, time seems to be only an abstract concept developed and elaborated by philosophers, scientists and physicists for their own purposes and concerns: apparently, we do not have any visible sense-organ dedicated to the detection of time. On the other hand, on the contrary, we can actually perceive the flowing of time: we experience it as proceeding either slowly or quickly, according to what we do and how we occupy ourselves. Consider for example the time spent in the waiting room of a railway station or of your dentist: if you do not do anything, and just wait for the train or your turn, time seems to drag and the train or your turn never seems to arrive: as the saying goes, a watched pot never boils. If in the same interval, on the contrary, you read something or speak with someone else your time seems to pass by smoothly and effortlessly.

Despite pervading every aspect of our life, time is nowhere. Because of this twofold and ambiguous aspect, we are not able to decide on whether time is something that really exists, something objective, or an illusion of our senses, a product of our mind, something subjective. Consequently, we often tend to explain it by either attributing what we subjectively feel to an external, objective entity, or ascribing what we think to be an abstract concept developed by philosophers and scientists to the innate and authentic human capacity of experiencing and evaluating time. In both cases, we explain time by resorting to concepts (the innate capacity of experiencing time, time as something existing in itself) that already contain in themselves, or are based on, the notion of time, thus giving up any possibility of analyzing and defining time independently of itself. Circularity seems then unavoidable.

In the following section I will exemplify some cases of circularity in studies of time drawn from different disciplines. I will dwell particularly upon linguistic and psychological studies, not disregarding however contributions from other fields.

2.1 Circularity in Philosophy

Philosophers have prevalently explained time as a succession or sequence of events, occurring either in the external physical world or inside the consciousness of the sentient subject, which can either be grouped in periods of variable durations, or conceived as following one another in a developing or evolving manner (for a critical and historical review of the philosophical explanations of time, see Ruggiu, 1998). While seeing time as occurring in the external, physical world has led to

the realistic conception of time as an intrinsic and objective quality of objects, existing independently of the subject (Plato, Newton), seeing it as occurring inside the consciousness of the sentient subject has led to the psychological conception of time as something inextricably related to, and derived from, the internal experience of the succession of ideas and psychical states (Saint Augustine, Locke, Berkeley, Hume).

Generally speaking, philosophers – whether they adhere to the realistic conception of time or to the psychological one - have encountered several difficulties in explaining time experiences without contradicting themselves. The main cause of the contradictions lies precisely in the circular explanation that they have given of time. If we consider the definitions of time given by the major philosophers we can easily notice the circularity they imply. For example, Hume and Berkley define it as a succession of perceptions or ideas, Leibniz as a continuum, that is, the order of what succeeds and cannot be simultaneous, Saint Augustine as the present, Aristotle as the becoming, Descartes as duration. But how can one explain, for instance, the experiences of "succession" or "sequence" without resorting to a more primitive experience, be it that of time or that of space? Indeed, one can experience a succession or sequence of events only after having experienced the fact that an event follows another in time or space, that is, the fact that the events are present at different times or places, and therefore, only after having had those peculiar experiences that are known as "time" and "space". Likewise, how can one have the experience of "order" without having previously adopted or identified a principle or criterion on and by means of which one could build the order? And where can one find such criterion or principle if not in time or space themselves, or in some more abstract entity derived from time and space, such as a scale or a series? Finally, how can one explain the experience of "duration", "becoming" or of something that "lasts" or "continues" without resorting to a "beginning" and to an "end", or to a "before" and to an "after", that is, without resorting to notions or concepts that already imply and presuppose the more basic experience of time?

These difficulties led Kant to put forward the third fundamental conception of time as an *a priori* form of sensibility: by doing so, however, he definitely gives up and precludes any possibility of further analyzing time experience in positive terms.

2.2 Circularity in Linguistics

In this section, I will deal primarily and extensively with a work by a cognitive linguist, Vyvyan Evans, both because it is specifically devoted to the semantic analysis of the lexical item "time", and because it is relatively recent. I will then briefly deal with Lakoff' and Johnson's analysis of

time. Finally, I will consider what has been, to my knowledge, the first serious attempt at getting out of circularity in linguistic studies: Silvio Ceccato's work.

2.2.1 Evans' analysis of time

Evans's work (2004) is a recent, in-depth study devoted to the semantic analysis of the word *time*. Evan's central thesis is that temporality is fundamentally subjective in nature and phenomenological in origin: "temporality is a real and directly perceived subjective experience" (Evans, 204, p. 31). Time is ultimately neither an empirical primitive, that is, a physical feature of an objective world, nor a mental achievement, an abstraction derived from the relations holding between external events, but an internal, subjective phenomenon related to the perceptual mechanisms that process sensory experience. Our awareness of time would be a consequence of the various "timing mechanisms" in the brain, such as the "perceptual moments" (Evans, 2004, pp. 22-27), which are necessary for and underpin perceptual processing. As such, time enters into our experience of everything as it is fundamental to the way in which perceptual processes operate: it is "a pre-requisite for abilities such as event perception and comparison, rather than being an abstraction based on such phenomena" (Evans, 2004, p. 9). That time is not an abstraction based on phenomena such as event comparison - a theory put forward by Gibson (1975, 1986), who argued that while events are perceivable, time is not, and by Lakoff and Johnson (1999), who argued that the concept of time results from an antecedent awareness of ongoing change exhibited by events in the world - is clearly shown by the fact that a) "we actually experience the 'passage' of time whether there has been a change in the world-state or not" (Evans, 2004, p. 64) as evidenced by situations of relative sensory-deprivation (such as windowless, sound-proofed cells) in which subjects are still aware of the passage of time, and b) our experience of time appears to be independent of the nature of the external events we are exposed to, that is, the way they change and move.

The hypotheses that time is fundamentally subjective in nature and that there exists a basic bifurcation in the conceptual system between concepts of subjective origin and concepts of external origin, explain what Evans calls the metaphysical and the linguistic problems of time. We are aware of time even if there seems to be nothing tangible in the world which can be pointed to and identified as time (the metaphysical problem of time), because time is subjective in essence and of internal provenance - temporality being "traceable to specific cognitive apparatus and processes" (Evans, 2004, p. 256) such as the neurologically instantiated temporal codes or rhythms that underpin perceptual processing - and because we can experience and perceive it directly. We use language pertaining to motion through three-dimensional space in order to think and talk about time

(the linguistic problem of time) because subjective information is difficult to conceptualize and verbalise. In order to conceptualize and verbalise it, we have to elaborate it in terms of external, inter-subjective sensory experience, such as the visual-spatial one.

According to Evans, the subjective experience of temporality is fundamentally durational in nature, and duration is what he calls the "sanctioning" sense associated with the lexical item *time*, that is, it constitutes the "citation" sense that language users would be most likely to produce in response to the question: "What does the word X mean?". As such, the durational aspect of temporality represents a prerequisite for the development (and not a consequence, as instead many authors claim) of the other important experiences that are usually conceived as being strictly linked to time, such as the awareness of change, the experience of succession, and the possibility of distinguishing past from present and from future. A number of reasons lead Evans to hypothesise that the experience of time is primarily durational in nature, and that duration constitutes the sanctioning sense associated with the lexical item *time*. Firstly, we can experience the "passage" of time independently of whether there has actually been a change in the world-state. Secondly, the experience of duration is independent of the nature of the external events: the experience of protracted duration can result from both states in which the stimulus array is impoverished and events that, on the contrary, are extremely rich in sense-perceptory terms. Thirdly, "it is our awareness of and ability to assess magnitude of duration which first and foremost allows us to distinguish past from present, and thus allows us to experience events as successive" (Evans, 2004, p. 112). Fourthly, the neurologically instantiated temporal codes that provide the basis for perceptual processing, and hence for our subjective awareness of time, are durational in nature. Fifthly, etymological evidence from linguistics suggests that it is "duration" which may constitute the historically earliest sense associated with the lexical item *time*.

Despite referring primarily to the durational aspect, "the lexical item *time* is conventionally associated with a range of distinct temporal lexical concepts" (Evans, 2004, p. 72). Evans, on the basis of three criteria or decision principles devised by himself (the meaning criterion, the concept elaboration criterion, and the grammatical criterion), is able to distinguish height different lexical concepts (or "senses") associated with the lexical item *time*: 1) the sanctioning sense of duration, from which the other senses appear to be derived. The duration sense is exemplified by sentences such as: "The relationship lasted a long/short time" or "It was some/a short/a long time ago that they met"; 2) the moment sense: "The time for a decision has arrived/come"; "What size was she at the time he was fourteen?"; 3) the instance sense: "Devine improved for the fourth time this winter when he reached 64.40 metres at a meeting in Melbourne"; "This time, it was a bit more serious because I got a registered letter"; 4) the event sense: "The young woman's time (=labour)

approached"; "His time (=death) has come/arrived"; 5) the matrix sense: "Time flows/runs/goes on forever"; "Time has no end"; "We live in time"; 6) the agentive sense: "Time is the great physician"; "Time, the avenger"; "Time has aged me"; "Time reveals all"; 7) the measurement-system sense: "In the 1850s Railway time was introduced as standard"; "Eastern Standard Time is five hours behind Greenwich Mean Time"; 8) the commodity sense: "Time is money"; "Time has become a scarce commodity"; "She has invested a lot of time in that relationship".

From the synchronic level, the range of distinct senses can be modelled in terms of a semantic network where the more peripheral members are less-related to the central sanctioning sense than the more central senses. Fig. 1 presents a diagrammatic view of the semantic network for *time*, where each node represents a distinct sense and arrows represent the degree of relatedness between distinct senses.

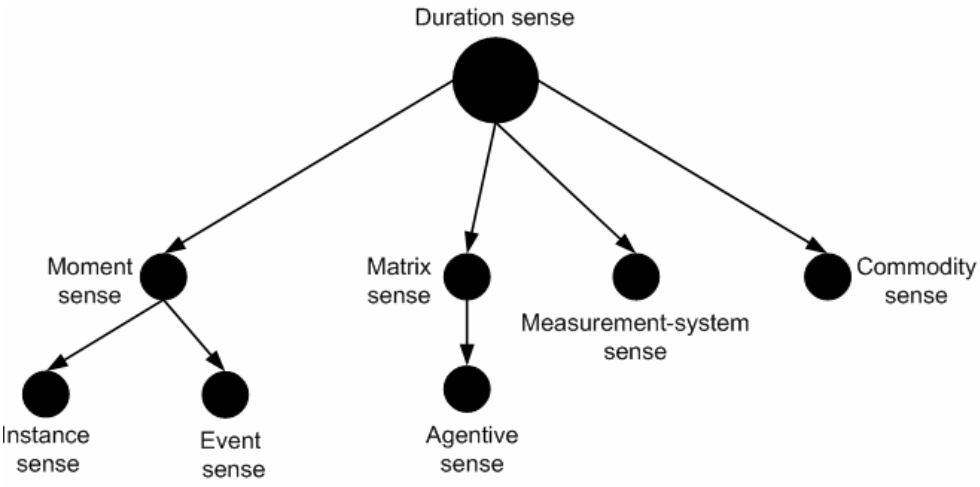

Fig. 1. The semantic network for "time" according to Evans

The fact that a word such as "time" has so many distinct senses can be easily accounted for if one adopts what Evans calls the "principled polysemy approach". This approach "seeks to account for the meanings associated with words as not being absolute and fixed, but rather as being capable of changing over time" (Evans, 2004, p. 79). According to the principled polysemy approach, lexical concepts are mutable and dynamic in nature; hence, through word-use, new lexical concepts or senses can be generated and associated with a particular word, thus extending the range of meanings associated with it. This process results in new lexical concepts becoming conventionalised, in such a way that they achieve mental representation independent of the

antecedent lexical concept which motivated their occurrence. The resulting distinct senses are the outcome of a dynamic process of meaning-extension, which is a function of language-use and socio-physical experience. An important role in this process is played by the mechanisms of "experiential correlation" and "perceptual resemblance" (Evans, 2004, pp. 46-49), the former giving rise to associations at the conceptual level due to tight and recurring correlations between two different kinds of experience, and the latter establishing connections between concepts on the basis of perceived similarities and shared characteristics. The mechanisms of experiential correlation and perceptual resemblances often give rise to implicatures or situated inferences, that is, contextually-derived meanings, which, through recurrence, can become conventionally associated with a particular lexical form associated with the context of use. Once an implicature has become conventionally associated with a particular form, this derived sense can, via "pragmatic strengthening" (Evans, 2004, p. 99-101), be employed in contexts of use unrelated to the original context which gave rise to the implicature in the first place.

Evans' analysis of time does not escape circularity. For Evans, the experience of time is primarily "durational" in nature: in fact, duration constitutes the sanctioning sense associated with the lexical item *time*. Duration, in turn, is defined as an "interval": "I will define duration as the INTERVAL holding or extending between the two boundary (beginning and ending) events" (Evans, 2004, p. 108). An interval, in turn, results from "succession": "Put another way, an interval of duration results from SUCCESSION. After all, if two events are not experienced as being successive we cannot experience duration" (Evans, 2004, p. 108). But "the notion of succession (…) derives from the phenomenon of duration" (Evans, 2004, p. 109): an observation, this, that is repeated in the following statement: "It is our awareness of and ability to assess magnitude of duration which first and foremost allows us to distinguish past from present, and thus allows us to experience events as successive. Hence, succession is a consequence of our awareness of duration" (Evans, 2004, p. 112). Circularity is thus assured (Fig. 2).

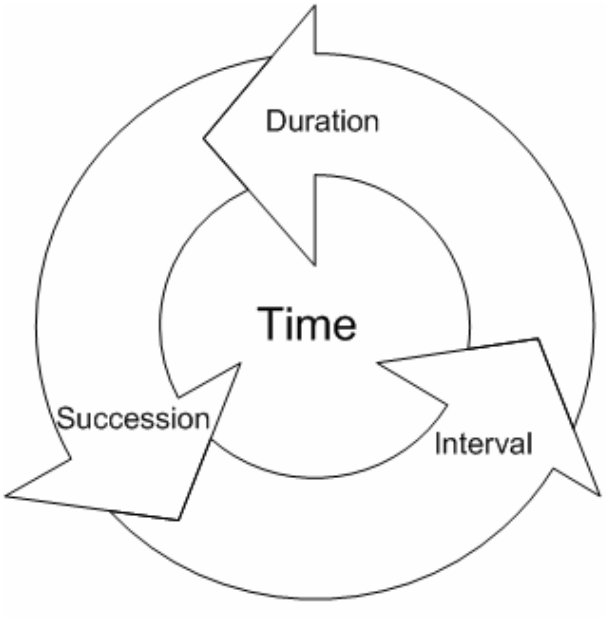

Fig. 2. The circularity in Evan's definition of time

There is no way in Evans' definition of time to get out of circularity. Time is duration, duration is an interval, an interval derives from succession, and succession derives from duration: the loop is closed. In Evans' formulation, all these concepts are so tightly entangled that is impossible to tell which one of them generates the others.

Certainly, duration is a very important aspect of the experience of time. But if one defines time as duration, one should be expected to be able to define duration independently of time. In order to define duration, Evans, on the contrary, resorts to concepts that already contain time as their constituent. The notion of "interval", for example, denotes a portion of time, something that has a "beginning" and an "end" (or an onset and an offset, in Evans' terms). But "beginning" and "end" are concepts that imply and presuppose the experience of time: in fact, to be able to speak about "beginning" and "end", one must already have experienced time.

Likewise, we cannot have an experience of "succession" or "sequence" without having had a more primitive experience like that of time (but also the experience of space could serve as the basis for the experiences of succession and sequence). Indeed, one can experience a succession or sequence of events only after having experienced the fact that an event follows another in time (or in space), or that events are present at different times (or places). Therefore, we can experience succession and sequence only after having had that peculiar experience that is known as "time" (or that peculiar experience known as "space").

Moreover, also the notion of duration, which Evans considers to be the sanctioning sense associated with the lexical item *time*, is not, strictly speaking, completely independent of the

experience of time. Indeed, if it is certainly plausible to define time in terms of duration, it is equally plausible to define duration in terms of time. However, the experience of duration entails the experience of something that "lasts", "endures", "goes on", "continues" or "develops", and this experience necessarily requires a "beginning" event, and sometimes also an "ending" event, that is, events which have a boundary nature. But an event can assume a boundary nature only when it is seen through the eyes of temporal experience.

Evans is not able to provide an independent definition of time, that is, a definition that does not refer to experiences, concepts and notions that in their turn are based on temporal experience. He defines time resorting to concepts such as duration, interval, and succession that presuppose and imply the experience of time: the *definiens* includes the *definiendum*, in an unavoidable circularity.

There is, however, one occasion in which he seems to realize the necessity to resort to an independent level of explanation: precisely, when he hypothesizes that our conception of temporality may ultimately be traceable to neurologically instantiated "temporal codes" underlying perceptual processing. An instance of temporal code is the "perceptual moment". A perceptual moment is a temporal interval characterized by the synchronized oscillations of neurons, which lasts for a short period of time, and is bounded by a silent interval before re-occurring. These synchronized oscillations allow information which is spatially-distributed in our brain to be correlated, thus giving rise to the correlation of sensory qualities, i.e., object perception. Therefore, the perceptual moment underpins perceptual processing and enables us to perceive. However, the perceptual moment is not only necessary for perceptual experience: it also constitutes "the cognitive antecedent of the concept of the present or now" (Evans, 2004, p. 26). Moreover, according to Evans (2004, p. 26), it would be the succession between a perceptual moment held in memory and the current perceptual moment that gives rise to the experience of duration. Therefore, the experience of temporality would naturally emerge from perceptual processing, with which it is so deeply entangled.

Also in this case, however, Evans is not able to avoid circularity. Ascribing - even if indirectly[1] - the origin of the experience of time to a neurologically instantiated temporal code or mechanism, Evans simply eludes the problem of giving a positive, non-linguistic definition of time, putting off its solution. What he does, actually, is to explain time through time itself. He explains temporal experience by using terms and concepts – such as neurologically instantiated "temporal" codes; "temporal" intervals; "synchronized" oscillations - that are already temporal categories, in that they

[1] See the following passage: "I must emphasise that I am not claiming that a neurologically instantiated temporal code forms the basis of our conception of temporality. […] However, in so far as temporal experience must ultimately derive from neurological processes, evidence of cognitive mechanisms and processes of his kind are suggestive that temporality is internal rather than external in origin, and may ultimately be traceable to specific cognitive apparatus and processes" (Evans, 2004, p. 256).

contain and are built on time. Indeed, how could you explain "temporal" codes, "temporal" intervals, and "synchronized" oscillations without resorting to the concept, or the experience, of time? Instead of providing an explanation of time independent of what we already know about time, and of the (conceptual and physical) tools humankind built precisely thanks to the notion of time, he bases his identification of the origin of the experience of time precisely on his knowledge of time: in fact, one can properly speak of "synchronization", "temporal" code and perceptual "moment" only when one already knows what time is.

Neither does Evans seem to offer or find a way out of circularity when he defines time in terms of the other lexical concepts: the moment sense, the instance sense, the event sense, the matrix sense, the agentive sense, the measurement-system sense and the commodity sense. Here, Evans' main aim is patently that of finding out and distinguishing the distinct lexical concepts associated with the lexical item time. It must be admitted that most of his analyses are very insightful and revealing, as when for example he distinguishes the matrix sense from the other senses by observing that the matrix sense is: a) something infinite, unbounded; b) a kind of backdrop against which other events occur; c) independent of events. It must be noticed, however, that he performs his analyses only by means of comparing the different senses, without resorting to any independent, non-linguistic level of analysis. One sense is defined by comparing it or referring it to the others, in a recursive way. Inevitably, these comparisons are always based on notions and concepts, such as "temporal", "duration", "interval", "moment", "sequence" and "event", which are not themselves defined in positive, non-linguistic terms, but which on the contrary refer circularly to each other. Consider for example the case in which Evans defines what distinguishes the event sense from the moment sense: "While the Moment Sense references a *temporal point* (within a particular *temporal event-sequence*), the Event Sense references an experiential point in an *event-sequence*" (Evans, 2004, p. 135) (italics are mine). As you can see, the Moment Sense refers to concepts ("temporal point", "temporal event-sequence") that in turn are temporal concepts or are concepts based on a temporal construction: that is, concepts that contain time as their main constituting element. The same can be said for the Event Sense. Consequently, Evans' analyses of the senses different from the duration one are also flawed by circularity.

Most probably, the pervasive presence of circularity in Evans' work is due to the strong relevance he gives to the notion of "concept" to the detriment of the notion of "meaning". Evans equates meanings with concepts: "to study linguistic meaning constitutes a study of the conceptual system" (Evans, 2004, p. 6); "language, and meaning, which it serves to express, must, on this view, be fundamentally conceptual in nature" (Evans, 2004, p. 509). Evans further specifies that concepts are mental representations, that is, information referring to experience that can be

represented, modelled and recalled for purposes of reasoning, abstraction, projection, etc. even when the experience is no longer accessible to focal consciousness (Evans, 2004, p. 39). However, the move of reducing the semantic level to a pure conceptual one (a move that is also made by some other cognitive linguists: see for example Jackendoff, 1983, 1992, and by cognitive psychologists: see Bloom, 2000) involves one major problem: if the notion of concept is not accompanied by an explanation of how a concept originates, what kinds of mechanisms determine it, how it works, and so on, the notion is completely useless. It is simply another linguistic way of representing and defining the meanings of words, an illusion of getting out of the linguistic level. It is true that Evans tries to generally motivate the development of conceptual structure and concept formation by means of mechanisms such as "perceptual analysis" (Evans, 2004, pp. 51-52), and to ground this development on our experiential and bodily basis. It is also true that he himself openly admits that while language is symbolic (it pairs a physical symbol with a meaning), meanings and concepts are sub-symbolic, that is, they are not linguistic: "meanings (or lexical concepts) are not primarily linguistic, but rather derive from perceptual analysis and are hence redescribed perceptions (i.e., they are embodied). In addition, they are informed by our interaction and experience with the entities they represent, and a whole welter of other background knowledge, such as knowledge gleaned through cultural transmission" (Evans, 2004, p. 53). But it does not go any further than that. For example, he does not investigate, nor proposes any hypothesis about, what it means to build perceptual-visual information, how it is or can be built, and how it can be redescribed in "conceptual" terms; more in general, what it means to say that concepts and meanings are not linguistic, what it means, and how it is possible, to redescribe something in non-linguistic terms, which kinds of operations (mental, physical, psychological?) and which combination of these operations produce a given concept, and so on. In a word, he does not provide any a-linguistic counterpart to language and concepts. On the contrary, he remains inside a purely linguistic level of analysis and description. Consequently, his analyses cannot escape circularity.

Reducing the semantic level to a purly conceptual one also involves some other kinds of problems. Concepts are not meanings: the former differ from the latter for some important reasons. Firstly, the meaning of a word is univocal: it is valid for, and shared by, everybody, and it has to be so to safeguard the communicative function of language; on the contrary, concepts are individual: everybody can have a different concept of that to which the word refers (everyone understands what the word "freedom" means, despite the fact that everyone can have a different concept of "freedom"). Secondly, the phenomenal, conscious experience of the meaning of a word is very different from that of the concept that the meaning of the word represents (even if when I say "dog" you understand what I mean, the concept I have of a "dog" may be very different from your concept

of "dog"). Thirdly, while all words have a meaning, it is not said that all words have an associated concept. Equating meanings with concepts, as Evans does, involves assigning the former the properties of the latter (and vice-versa). One of the direct consequences of this operation is that of confusing the semantic level of analysis with other levels of analysis, such as the conceptual or the pragmatic ones – a confusion which seems to be implied by the encyclopedic view put forward by Evans (2004, pp. 53-54). It is certainly true that words represent a point of access to a kind of knowledge that is usually more general and wider than that specifically and immediately transmitted by their meanings. It must be noticed, however, that one needs some time to pass from the moment in which one understands the meaning of a given word to the moment in which one can imagine, remember or think about what that meaning may refer to. When we hear a certain word, for instance "dog", we understand the meaning of the word almost immediately; however, we need some more time to pass from the meaning to the images, thoughts, memories or emotions (that is, what constitute our personal experience and concept we have of dogs) that may be associated with it. Usually, in normal, daily speech, we do not pass from the meaning of every word we hear to the concept or the bulk of our personal experiences it may elicit, but only for some of the words we hear. This means that meanings are processed at a different stage from that at which concepts and more in general past experiences are processed, and that concepts and experiences require a different kind of processing from that required by meanings. If it so, it seems useless and out of place to call for "the totality of knowledge we possess concerning a particular entity or experience" (Evans, 2004, p. 54) in order to analyze the meanings of words.

2.2.2 Lakoff' and Johnson's analysis of time

According to Lakoff and Johnson (1999), time is something created via our bodies and brains: it is a human concept cognitively constructed by two processes, one metonymic, based on correlations with events, and one metaphoric, based on motion and resources. While the cognitive mechanism of metonymy allows us to have a sense and an experience of time, the metaphoric allows us to conceptualize time in terms of motion and space.

Our direct sense and experiences of time, what Lakoff and Johnson calls the "literal" aspects of time, such as its directionality and irreversibility, arise from, and are grounded in, other experiences: the experiences of events and their comparison. This derives from the fact that we cannot observe time itself; we can only observe events and compare them: "Literal time is a matter of event comparison" (Lakoff and Johnson, 1999, p. 139). Our real experience of time is always relative to our real experience of events. To say that an event lasts a certain time is to say that it is

compared with other events that have a regular and iterative occurrence, such as the motion of a pendulum, the movement of the sun, or our bodily rhythms: "The sense of time in us is created by such internal regular, iterative events as neural firings" (Lakoff and Johnson, 1999, p. 138). In other words, there are iterative events against which other events are compared: "We define time by metonymy: successive iterations of a type of event stands for intervals of 'time' " (Lakoff and Johnson, 1999, p. 138).

According to Lakoff and Johnson, literal time is only the beginning of our concept of time. We use a number of metaphors in conceptualizing time – time as a flow, time as a continuous unbounded line, time as a linear sequence of points, etc. –, and it seems unlikely that we can think and talk about time without those metaphors: "such a metaphorical conceptualization of time is constitutive, at least in significant part, of our concept of time" (Lakoff and Johnson, 1999, p. 166). Very little of our understanding of time is purely temporal: "Most of our understanding of time is a metaphorical version of our understanding of motion in space" (Lakoff and Johnson, 1999, p. 139). This is due to the fact that motion is a more primitive concept than time. Time metaphors are so pervasive, occur so frequently, and are present in so many different languages around the world because they arise from our most common everyday embodied experience of functioning in the world: "Every day we take part in 'motion-situations' - that is, we move relative to others and others move relative to us. We automatically correlate that motion (whether by us or by others) with those events that provide us with our sense of time, what we call 'time-defining events'. In short, we correlate time-defining events with motion (…). Thus, in a motion-situation, motion is correlated with time-defining events" (Lakoff and Johnson, 1999, p. 151). The spatial metaphors for time are an automatic part of our cognitive unconscious that structures the very way we experience time.

As we have seen when dealing with Evans' work, Lakoff' and Johnson's position that the concept of time results from the comparison of events which inhere in the world raises some reasonable and legitimate doubts, especially because the experience of time appears to be independent of the nature of the external events we are exposed to, that is, how much change is occurring. As shown for example by Flaherty (1999), the experience that time is passing slowly, a phenomenon which Flaherty labels as "protracted duration", can be brought about by opposite situations: indeed, it can result from events that are extremely rich in sense-perception terms – such as when situations explode suddenly into violence and danger, in shocking circumstances, when unexpected events occur, and so on –, but also from events in which the stimulus array is impoverished – as in boredom, waiting periods, etc.

In my opinion, however, another and more relevant objection can be raised against Lakoff and Johnson's position. To claim that the sense of time is created by "such internal *regular, iterative* events as neural firings", and that the sense of duration of an event results from comparing the event "with some *iteration* of such events as the motion of a pendulum or the spinning of the wheels of the clock" (Lakoff and Johnson, 1999, p. 138; italics are mine), is patently to put forward a circular definition of time. Concepts such as "iteration" and "regular", let alone "clock", can only be obtained and built up by means of a more basic and primitive conceptual tool such as time. Indeed, how can you judge or estimate an event as "iterative" or "regular" without an independent parameter against which you can compare the event itself? How can you say that something repeats "regularly" if you do not have an independent criterion or scale by means of which you can measure and ascertain the "regularity" of the repetition? How could you even speak and conceive of "regularity" and "iteration" without having previously adopted a principle on and by means of which you can build it? And where does this criterion, parameter or principle lie if not in a basic concept such as that of time (or in some other abstract scale derived from time)?

The regularity of perceived successive events is still not the perception of the regularity of events. That event X *follows regularly* event Y is given neither in X nor in Y, but is added by us, by one or more supplementary mental acts of ours. And there is no doubt that these acts consist, at least partly, in: a) correlating X with Y by means, and on the ground, of an irreversible – i.e., "temporal" – scale; b) determining the order of the events in the sequence (i.e., X comes after Y); c) determining, on the basis of the temporal scale, the distance between X and Y; d) adopting such a distance as a basic, reference unit against which the distance between the events composing each further repetition of the sequence Y→X is compared (as a consequence of the comparison, the repetition of the sequence Y→X can turn out to be either "regular", if the distance between the events of the repeated sequence is equal to the reference unit, or "irregular", if it is not). Only after having performed such operations can one speak of, conceive of, and perceive the regularity with which events repeat and occur.

Lakoff and Johnson's statement that: "The sense of time in us is created by such internal regular, iterative events as neural firings" (1999, p. 138), reminds me of the evolutionary proposal put forward by the psychologist Goodson (2003). According to Goodson, time is the outcome of the organizing processes of perception, which in turn express and reflect the perpetual interaction between the organism and its ever-changing environment. Rhythm marks the fluctuations of energy and the movement of things in the natural environment: winter turns into summer, the moon waxes and wanes, and so on. "Organisms evolved in a context of such rhythms, and they reflect them in their processes" (Goodson, 2003, p. 137). There are rhythms in the homeostatic activities of the cell,

in the beating heart, in the elimination of waste, in the menstrual cycle of the human female, and so on. All these internal rhythms or biological clocks reflect recurrent changes in the environment, and each of them determines the tempo of some critical activity performed by the organism.

The cadence of events important for survival is thus internalized into the organism in various ways. In Goodson's view, the rhythm of responses triggered and sustained by cyclical stimuli becomes the basis on which the experience and perception of time is built: "Where Kant believed that time was an inherited subjective intuition imposed upon by experience, I believe that our perception of time is derived from repeated tempos given in experience" (Goodson, 2003, p. 139). More precisely, human beings' experience of time is a learned perceptual structure built up in much the same way as those representing size and shape constancy. That is, the individual's multiple and recurring experiences become fused and summarized into a *subjective frame of reference* (or chronocept) which the individual uses each time he or she thinks about time in abstract or makes a judgment of how much time has passed:

> In the human being, the internal rhythms of breathing, heartbeat, and other biological processes combine with such recurrent and systematic external changes as the alternation of night and day, the arrival of the postman, the movement of hands on a clock, and so on to become subsumed into the time constancy subjective frame, which then provides the basis for time judgments thereafter. This time constancy frame of reference is automatically imposed, and provides a functional background relative to which all tempos and events are automatically evaluated (Goodson, 2003, p. 138).

In other words, this time constancy subjective frame (or chronocept) provides an enduring basis for the judgment of tempo, and it is what we are referring to when we use the word time.

In my opinion, there can be no doubt about the evolutionistic origin of the notion of time, as well as for most of, if not all, the notions and concepts produced by the human being. We are what we are (at least, to a considerable extent) because of the continuous selective pressure exerted on us by the environment and other creatures: we represent within our processes and structures the shaping conditions that determined our evolution. Likewise, there is little doubt about the fact that we experience the kind of time (and space) we experience, and in the specifically human way we experience, because we have developed in such a specific way and environment.

However, describing the circumstances that favoured the appearance and development of something is not yet explaining how that something works and of what it consists. A pure evolutionary description can certainly account for the reasons that brought human beings to consciously experience time, and perhaps also for the fact that their experience of time is characterized by certain specific features. But this evolutionary description is not yet an explanation of the mechanisms that underlie the experience of time, and make it possible. Describing the evolutionary "why" is not yet explaining the functional "how": one cannot mistake one level of analysis and explanation for the other.

Moreover, the idea that: "our perception of time is derived from repeated tempos given in experience" (Goodson, 2003, p. 139), and that the chronocept reflects, in a summarized way, the rhythms in which the events of the external environment and of our organism occur and repeat, entails some fundamental drawbacks.

Firstly, it cannot account for the fact that psychological time, that is, time as it is experienced subjectively, does not reflect, and is different from, physical time, that is, the time of physics. As we will see more extensively in a following paragraph devoted to the relationship between physical time and psychological time, phenomenal, subjective time cannot be reduced to the time of physics. If our experience of time really reflected, albeit in a summarized way, the rhythms of the external environment and of our organism, there should not be all those differences and discrepancies between phenomenal time and physical time that psychological experiments have highlighted (Vicario, 2005).

Secondly, the various rhythms of the environment and of the organism are so different both in degree and type that it is not at all easy to understand how they can be "summarized" and in what this summarization consists. How can one combine and reconcile such different rhythms as the breathing rate and the lunar phases? How can a summarized, mean rhythm account for as irregular rhythms as the menstrual cycle and heartbeat? (By the way, should the fact the women have a menstrual cycle imply that their chronocept differs from men's?)

Thirdly, it seems to overlook the fact that explaining subjective time by resorting to physical time, whether under the form of the rhythms of the environment or the internal rhythms of the organism, does not explain time at all, but simply put its explanation off. Calling into question external rhythms or changes such as the alternation of day and night does not clear up the mystery of time any more. What is a "rhythm"? What is an "alternation of day and night"? What do they consist of? How do you explain them? Are they self-explaining phenomena and notions? Or do they need that someone else (such as a human being) perceives, conceives of and explains them?

In my opinion, the latter solution is the only possible one: someone is required to bring them about. Indeed, in order to be able to speak and conceive of - let alone explain - "alternation", one has at least to perceive that there are two phenomena ("day" and "night"), that they are different, to think of them as being related to each other, that their relationship involves a given order of occurrence (first comes night, then comes day: that is, they cannot come together simultaneously), and that they repeat in accordance with the order of occurrence. Without the contribution of such additional operations, and, consequently, without the existence of an operating subject performing them, there could not be "alternation" between events, nor any other kind of relationship between them, nor even the events themselves. Evidence for this is also given by the fact that what someone

describes as an "alternation", someone else could as well describe in some other ways, such as a "substitution" (of day for night), a "change" (from night into day), a "progression" (from night to day) or a "sequence" (of night and day), simply by slightly changing one or more of the additional operations. In conclusion, also physical time is not given once and for all as a fixed reality, but in order to come into reality, be seen, conceived of, and explained, it needs a perceiving and cognizing subject able to perform some additional (mental) operations.

2.2.3 Ceccato's analysis of time

To my knowledge, the first serious attempt in linguistic studies at getting out of circular definitions was made by Ceccato (Ceccato, 1969, 1972, Ceccato & Zonta, 1980), who always insisted on the necessity of looking for an a-linguistic counterpart of language. Indeed, Ceccato strived for providing definitions of the meanings of words that were not so much *linguistic* as *operational*, that is, definitions deriving from analyses carried out in term of operations, namely, mental operations. In this view, he carried out many analyses of meanings in terms of attentional operations, including those of space and time. He symbolized with an S the single attentional state, and used the sign ‾‾ above the attentional states to indicate their combination and the order in which they are combined. These are Ceccato's analyses of space and time:

> Si prenda un oggetto molto piccolo, magari la pallina di una penna a sfera, e si cerchi di considerarla come 'spaziale'. Ci si accorgerà di doverla mentalmente rompere, articolare, almeno per un momento, in due pezzi, avvertendo in mezzo una specie di intervallo e continuando d'altra parte a sentire l'unità della pallina. Se traduciamo in termini operativi queste impressioni, descriviamo la categoria di spazio come composta da una cosa ($\overline{S\,S}$) e una pluralità ($\overline{S\,S}\,\overline{S\,S}$), ed è lo stato di attenzione centrale, del plurale, a generare la sensazione di intervallo. In altre parole diremo che lo spazio corrisponde all'articolare pluralisticamente 'cosa'. (…) La categoria di 'tempo' rovesci(a) la situazione: si parte cioè da una pluralità (pallina al tempo 1, pallina al tempo 2) e si 'restringe', unifica, condensa questa pluralità in 'cosa' (Ceccato & Zonta, 1980, pp. 209-210).

> (I translate into English: "Take a very small object, such as the ball of a ballpoint pen, and try to consider it as being 'spatial'. You notice that, at least for a moment, you have to mentally break it down and articulate it into two pieces, feeling between them a kind of interval and continuing at the same time to sense the unity of the ball. If we were to translate these impressions into operational terms, we would describe the category of space as being composed of a thing ($\overline{S\,S}$) and a plurality ($\overline{S\,S}\,\overline{S\,S}$), and it is the state of central attention, of the plural, which generates the sensation of an interval. In other words we would say that the category of space corresponds to articulating pluralistically 'thing'. (…) The category of 'time' inverts the situation: that is, we start off with a plurality (ball at time 1, ball at time 2) and we 'narrow down', unify, condense this plurality into 'thing' ").

As we can see, for Ceccato, the experience of time is opposed to that of space: it is an experience in which a situation that is composed of a plurality of events or objects, that is, where an event or object is mentally constructed (whether in the from of a perception, an idea or something else) more than one time, turns into a situation composed of a single event or object. Ceccato's analysis rightly

points out one of the fundamental features of time experience: the fact that when we see an object from the temporal point of view, or when we live a situation as unrolling or evolving in time, we *repeatedly* experience that object or situation, we perceive, see, imagine, consider or think about it more times.

His analysis however, while representing a first important attempt at describing time experience without using elements that in their turn derive from and are built on time experience, is unable to account for at least three fundamental features of time experience:

a) the fact that by means of time experience we are able to order events, that is, to establish that a certain event A comes before event B. Ceccato completely leaves the explanation of our capacity to order events to the intrinsic *succession* or *sequence* of the two categories of "thing" ($\overline{\text{S}\text{S}}$) composing the category of "plural" ($\overline{\text{S}\text{S}}\overline{\text{S}\text{S}}$): the order in which events occur is determined then by the bare succession or sequence of the categories of "thing". In fact, he mentions: "ballpoint at time 1, ballpoint at time 2", without explaining how it is possible for us to determine "time 1" and "time 2", that is, how we can construct, perceive or conceive of a given event or object as occurring at "time 1" instead of at "time 2". But how can a succession or sequence explain time order? To have a succession or sequence of things or events we must have a "before" and an "after", or a "now" and a "then", or a "here", and a "there": one thing or event must follow another in time (or space), and we must know what "to follow" means and implies, otherwise we could neither see, perceive or conceive of a temporal (or spatial) succession or a sequence of things or events, nor a bare a-temporal and a-spatial one ("first", "second", third", and so on), but only have a kind of experience such as "one thing, another thing, still another thing, and so on": an updated now without any awareness of succession or sequence. The very notions and experiences of succession and sequence rely on the more basic experiences of time and space;
b) the fact that our evaluation of the duration of a given period - say, an hour – depends on how much attention we have spent either to perform a given activity during that period (as one can easily notice, for instance, during severe effort of attention time is long to us, during easy employment short), or to focus on or evaluate time itself (as James observes: "a day full of waiting, of unsatisfied desire for change, will seem a small eternity […] It comes about whenever, from the relative emptiness of content of a tract of time, we grow attentive to the passage of the time itself", James, 1890, Vol. I p. 626). This latter kind of duration judgement, which is known also as "prospective duration judgment" or "experienced duration", depends highly on attention (Block and Zakay, 2001, and Tse et al., 2004). As Block and Zakay point out: "most theorists propose attention-based models of experienced duration (…) In these models,

experienced duration increases to the extent that a person allocates more attentional resources to processing temporal information" (Block and Zakay, 2001, pp. 68-69).

c) the fact that psychological time moves only in one direction, that is, it is irreversible.

2.3 Circularity in Psychology

The problem of circularity in psychology is certainly not a new one. William James (1890) observed that the explanations put forward by many authors (for example, Drobisch, Guyau, Herbart, Lipps, Volkmann and Waitz) who had tried to account for what cerebral processes cause the sense of time, simply begged the question: indeed, their explanations, resorting to explanatory notions (such as "elapsed", German, "durchlaufene") that already contained within themselves, and were based on, the experience of time, did not explain time experience at all, but simply *described* it. He also pointed out the fallacy implied in one of the most common and instinctive way of accounting for the sense of time, namely, the explanation based on the observation that phenomena succeed one after the other. The line of reasoning followed by those who resort to this kind of observation is more or less the following. 1) Outer forces smite first upon the brain, and then upon our mind: consequently, our perceptions correspond with, and mirror outer reality; 2) Events take place in time; therefore, our perception of events also take place in time: the time-relations of our perceptions furnish then a copy of the time-relations of the perceived events; 3) The mind, which can feel its own states, also feels the time-relations of its states: therefore, time, sequences and durations become known by the mind. In other words, the mere existence of time in those changes outside of the mind which affect the mind is a sufficient cause for why time is perceived by the mind. As James observes, the fallacy of this line of reasoning lies in the fact that:

> even though we *were* to conceive the outer succession as forces stamping their image on the brain, and the brain's successions as forces stamping their image on the mind, still, between the mind's own changes *being* successive, and *knowing their own succession*, lies as broad a chasm as between the object and subject of any case of cognition in the world. *A succession of feelings, in and of itself, is not a feeling of succession. And since, to our successive feelings, a feeling of their own succession is added, that must be treated as an additional fact requiring its own special elucidation*, which this talk about outer time-relations stamping copies of themselves within, leaves all untouched (James, 1890, Vol. I, p. 629).

The successive perceptions or ideas are not yet the perception or idea of succession: succession in thought is not the thought of succession. If idea or perception A follows idea or perception B, consciousness simply exchanges one for another. That B comes *after* A is given and implicit neither in B nor in A: it is a *third* kind of conscious experience that is brought forth by us, that is, the product of some additional mental operations we perform and through which we correlate A and B.

2.3.1 The internal-clock models

Another very popular and, in my opinion, deceitful way of explaining time in psychology is that of resorting to the metaphor of an internal or inner clock, whether its workings are occasioned by chemical, neurological or physiological processes.

Hoagland (1933, 1935), for example, hypothesized the existence of a specific chemical clock located in the nervous system that furnishes its possessors with a subjective time scale. He based his hypothesis on the observation that various physical changes taking place in the environment, such as variations of body temperature, modify time-related behaviors and judgments: which makes it plausible to believe that the latter are determined by the working of a chemical clock.

Wiener (1948) suggested that the alpha waves of the EEG could act as the "ticks" of a biological clock and that the alpha rhythm might provide the physiological mechanism underlying our "organ" of time.

Treisman (1963) proposed a model of the internal clock composed of a pacemaker producing a regular series of pulses, a counter recording the number of pulses that arrive at a given point, a store and a comparator, into which the result of the activity of the recorder is entered. He also attempted to determine whether the frequency of this hypothetical pacemaker is related to the alpha-rhythm, but his data failed to support the notion of a correlation between the two (Treisman, 1984).

More recent models (for a review, see Wearden, 2001), such as the pacemaker-accumulator clock or the one proposed by the "scalar expectancy theory" (SET), represent a refined elaboration of Treisman's proposal. Let us examine, for instance, the SET model, of which Fig. 3 provides a diagram. The SET model is composed of three parts: a pacemaker-accumulator, a memory system, and a comparison or decision process. To understand the operation of such a model, consider the problem of timing the duration of a stimulus t_1 through comparison with the duration of another stimulus, t_2 (whether, for example, they are equal or different in length). Onset of stimulus t_1 causes the switch connecting the pacemaker and accumulator to close, allowing pulses, that is, the "ticks" of the inner clock, to flow. Offset of the stimulus causes the switch to open, cutting the connection: the accumulation of pulses by the accumulator is then stopped. The memory system allows duration representations to be stored either in a long-term memory or in a short-term memory. Thanks to the memory system, the duration of the first stimulus t_1 can be stored until after the second one, t_2, has been presented: a comparison between the two stimuli is then made possible. Finally, t_1 and t_2 are compared and a response can be delivered.

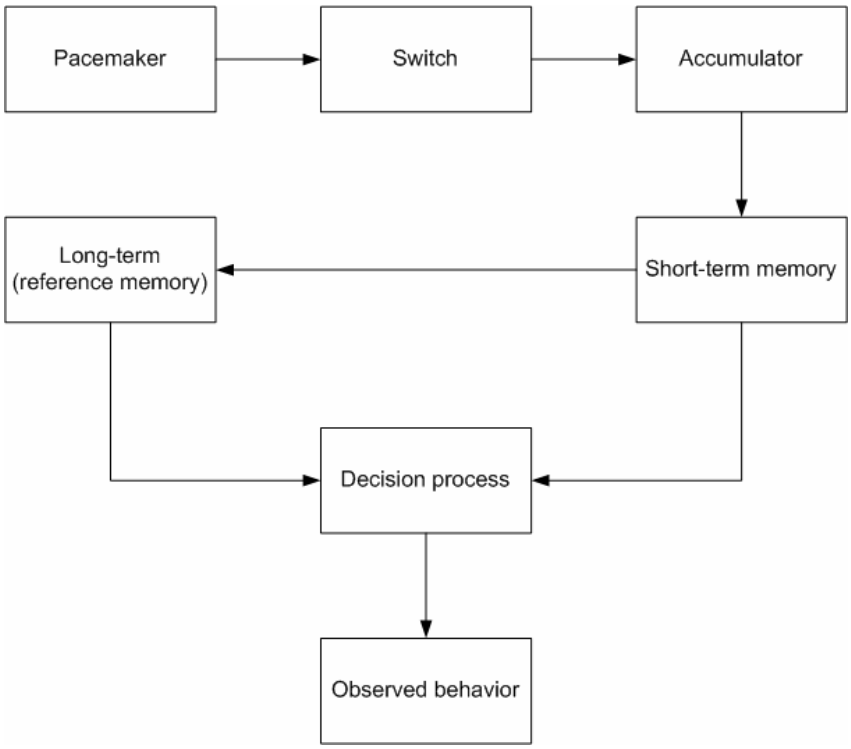

Fig. 3. The temporal information processing system proposed by the Scalar Expectancy Theory

The internal-clock models can account for some phenomena, such as, for example, the differences in judging the duration of auditory stimuli versus visual ones. It has been known since the nineteenth century that for the same real-time duration, auditory stimuli appear longer than visual ones. Wearden et al. (1998) showed that the difference in duration judgments between auditory stimuli and visual ones can be modelled in terms of a difference in pacemaker speed for the two modalities. The internal-clock models also account for the differences in duration estimates occasioned by techniques that apparently change pacemaker speed: Penton-Voak et al. (1996) showed that brief trains of clicks (from 1 to 5 seconds long) changed the subjective duration of auditory and visual stimuli, in a manner consistent with the idea that pacemaker speed had been increased by the clicks.

However, the internal-clock models cannot account for everything. As Wearden observes: "not all the timed behaviors of humans are explainable by internal clocks" (Wearden, 2001, p. 38). While the internal-clock models are used to account for prospective timing tasks, where subjects are alerted in advance that time judgments will be required, they cannot be used, for example, to account for retrospective timing tasks, where subjects do not know in advance that they will later be asked to judge the duration of a time period: retrospective timing tasks are, on the contrary, explained using models involving the number of contextual changes which occurred during the

period whose duration has to be judged (Block and Zakay, 2001), or the amount of information processed (Ornstein, 1969).

Moreover, various kinds of criticisms have been raised against the models based on the idea of an internal clock. According to Block (1990), for example, internal-clock models are certainly suited to handling relatively simple relationships such as that between body temperature, arousal, and response rate; however, they seem unable to explain why cognitive kinds of factors, such as strategies, influence temporal behavior and experience. Furthermore, he observes that internal-clock models seem inadequate to explain the inherent inaccuracy of human duration judgments, that is, the fact that organisms provided with such a precise mechanism as an internal clock very often exhibit inaccurate timing behaviors. Still Block (2003) points out that the internal-clock models have some more specifically technical and methodological drawbacks: 1) no constant-rate pacemaker has been identified in the brain; 2) researchers advocating internal-clock models have mainly studied rats and pigeons; 3) most of the evidence comes from a few relatively simple paradigms (such as the peak procedure and the bisection task), from studies in which animals estimate the duration of a single stimulus or an interval between two stimuli, and from experiments during which no external stimuli are presented; 4) internal-clock models are not easily able to explain effects of attention on psychological time; 5) many of the findings that internal-clock models explain are generic, that is, they are not unique to the time dimension. The same findings of the internal-clock models could be explained by models composed of very basic modules, such as a perceptual system, without needing to resort to an additional component such as the pacemaker: as Block states: “With only slight modification (e.g., substituting external stimulus information for the pacemaker), scalar-timing models could easily become scalar-perceiving models” (Block, 2003, p. 44); 6) the typical internal-clock assumption that time estimates are a linear function of physical duration is not widely supported.

Ornstein (1969) raises some other interesting questions concerning the individuation of the internal clock. Apparently, human beings, as well as other animals, are provided with a number of different mechanisms that all could equally and finely do as internal clocks: heart rate, breathing rate, cellular metabolism, toe-nail growth, alpha rhythm, etc. What are the criteria for judging a given physiological process to be an internal “chronometer”? Why could hair growth or toe-nail growth rather than alpha rhythm not be designated as the internal time keeper? Moreover, as Ornstein observes, these different mechanisms do not always run at the same rate: breathing rate, for example, is different from brain cell metabolism. Therefore, which one of them could be the “biological clock”? Is there a rate or rhythm that could be considered as more basic than the others?

Or is it a combination of some or all of these internal periodic rhythms that must be considered as the internal time keeper?

In this regard, Richelle et al. (1985, p 90) go so far as to pose the provocative question: "Why not admit that there are as many clocks as there are behaviors exhibiting timing properties?". This nasty admission definitely confirms the uselessness and lack of parsimony of the notion of internal clock for a general analysis and explanation of time experience. If there are as many internal clocks as time behaviors and experiences, what is the epistemological and practical usefulness of the notion of internal clock, given the wide variety and complexity of the experiences of time? We can not only perceive and estimate as many different time experiences as long and short durations, simultaneity, succession, and temporal perspective, but also perceive each of them in different ways, according to how many different conditions such as body temperature, contextual changes, information load, fatigue, etc. vary. If we suppose that every behavior exhibiting timing properties requires its own internal clock, then what we can expect is only an incontrollable expansion of the number of these clocks. To reiterate a well-worn dictum, in science we strive to explain the most with the least: any explicative model that increases complexity instead of reducing it must be rejected.

Obviously, as it has been observed (Ornstein, 1969, Block, 1990, Vicario, 2005), the notions of internal clock or biological clock may have some relevance in the explanation of periodic physiological rhythms *per se*. Undoubtedly, such notions seem to be necessary if one wants to explain, for example, human movement timing and motor programs, and, to a certain extent, also prospective timing (Block and Zakay, 1996, 2001, Zakay and Block, 1997). Indeed, as I will show later in the article, it seems reasonable to suppose that some kind of mechanism - akin to, *but anyway different from*, a clock or a pacemaker - supplying in a more or less regular way the basic material on which to build and perform temporal processing, is involved in time experience in general.

However, this is not sufficient. What seems to me highly implausible is the belief that merely naming a given process as a "time keeper" automatically suffices to appoint it as the mechanism responsible for time experience. A counter or a timer, like any clock, can only provide the raw material necessary for counting. But there must be someone who performs the counting. As Vicario argues: "*The clock says the hour only when we look at it*" (Vicario, 2005, p. 165). It is we who assign the physical mechanism - whether it is a pendulum, the sun, a clock, or something else - the capacity to trace the flowing of our conscious experiences and to estimate their duration. To realize this, just consider the fact that a clock which is stopped or not-working, despite not measuring any actual time, nonetheless can still be interpreted by an observer as telling the time!

The big problem with explaining time experience in terms of an internal or inner clock resides in the circularity it implies. Clocks, as well as chronometers, watches, sand-glasses, and the like, were developed on, and thanks to, the original capacity human beings have to subjectively experience time: they are the product of our mental, physical and psychological capacities. Well, by explaining temporal experience through the notion of internal clock, one simply begs the question, because one uses the result of an activity, that is, what can be done and developed thanks to that activity, in order to account for the activity itself: it would be tantamount to using the notion of flour to explain how a mill grind grains, what machinery perform the grinding, on what physical principles, and so on!

Moreover, the limitedness of the hypothesis of the internal clock is further highlighted by the consideration that clocks are just one of the possible products that were developed out of the various kinds of temporal experiences human beings can have. Indeed, clocks are products based on one specific (albeit very basic) kind of temporal experience: the continuous flowing of our conscious experiences. However, we can have some other kinds of temporal experiences as well: the experience of their succession, simultaneity, rhythm, duration, instantaneity, irreversibility, and so on. While clocks and watches were developed in order to account, as precisely as possible, for the continuous flow of our conscious experiences, chronometers were developed in order to measure their (typically short) duration, metronomes to beat time, synchronization systems - such as those used in telecommunications - to maintain simultaneity, calendars were developed to account for irreversibility (of days, weeks, seasons, years, etc.). Each one of these instruments has its own specific function, and cannot (or can hardly) be used to perform any of the functions performed by the other instruments. You cannot use a calendar or a pocket diary to measure what a watch measures (a pocket diary cannot tell you what time it is now); conversely, you cannot use a watch to account for what a calendar or a pocket diary accounts (if you are alone on an island, and you forget what day of what month of what year it is today, you cannot count on your watch to get this information - unless of course your watch is provided with some kind of calendar). When it is possible to use one of these instruments in place of one of the others (as when, for example, you use a watch to beat time), you have to intentionally change your usual attitude towards it (when beating time, you will pay attention not so much to what time it is, as to the number of elapsed beats, and to the fact that they have to repeat after a certain number of them elapsed). Clocks therefore can account only for the continuous flowing of our experiences, but not for the other temporal experiences. Consequently, resorting to clocks to also account for the other kinds of temporal experiences would turn out to be inadequate.

2.3.2 Models alternative to the internal-clock model

2.3.2.1 The storage-size model

As I said at the beginning of this paper, one of the main negative impacts and perverse effects circularity has in scientific explanation, and on knowledge development in general, is that of diverting scientists' attention from taking into due consideration the fundamental importance played by their mind in constructing and shaping the phenomena they are investigating. The notion, or metaphor, of an internal clock has precisely this very property: giving an intuitive, apparently easy, immediate and appealing, but illusionary, solution to (at least some of) the problems related to how we humans, as well as some other species, can estimate time and coordinate motor programs, and how periodic physiological rhythms can occur, and so on, it distracts researchers' attention from taking into due consideration the mental processes that contribute to shape, give form to, and produce the experience of time, thus blocking the advance and growth of human knowledge.

Ornstein was well aware of the treacherous mechanism of the internal-clock model, and of its fatal consequences for the study on mind and human cognition. For him, this model was based on the idea that "there would exist a 'real' time independent of us" (Ornstein, 1969, p. 34), that is, an external time existing outside the organism, and that we are provided with an "organ" of time experience (namely, the internal-clock) capable to measure the real, external time. According to this idea of an "external time", our role in time experience would be a very limited and restricted one: we would be relegated to acting as a passive tool which can only mechanically and automatically register and measure what is going on "out there".

As Ornstein argues, this is a very unrealistic picture of time experience: a picture which cannot account for the fact that our experience of time is strongly influenced by cognitive factors such as the amount of information processed during the interval whose duration has to be estimated, the complexity of the processed stimuli, the way stimuli are stored in memory, memory load, the observer's level of attention, and so on. In a series of experiments on remembered duration, or retrospective timing task, in which subjects were kept unaware that their experience of time was being studied, Ornstein (1969) found that either storing more stimuli during a time period, storing more complex stimuli, or storing them in a more complex way, lengthens subjects' experience of duration. In Experiment I, for example, subjects had to listen to three tape recordings, each of the same clock length (9 min. and 20 sec.), on which events (tones of 0,2 sec.) appeared at three different rates: on one tape, events appeared at the rate of 40 per min., on another tape at 80 per min., and on still another tape at 120 per min. Subjects judged the 80 per min. condition to be

longer than the 40 per min. condition, and the 120 per min. condition to be the longest. He found that some other cognitive factors, such as familiarity with stimuli, learnt coding schemes, the pleasantness of stimuli and their propensity for being retained in memory, are brought to bear on duration judgment: when for example subjects were taught different schemes to code the same event, they tended to judge longer the event in which more was construed to have occurred (Experiment VI); likewise, when conditions were arranged so that subjects in one condition forgot more than subjects in another, the experiences co-varied with the amount in storage (Experiment VII). Ornstein also showed that when the information stored in memory is somewhat manipulated and altered, the experience of duration is altered correspondingly: by having subjects recode a "random" or complex stimulus into a simpler one after the interval was completed, their experience of duration was shortened relative to those who did not recode the stimulus (Experiment VIII).

On the basis of all this evidence, Ornstein inferred that time experience can be best accounted for by the "storage size" metaphor, which explains duration as a mental construction formed from the size of storage of the information in a given interval: that is, it is the information remaining in storage that determines duration experience. According to this metaphor, anything which alters the size of storage of the information in a given interval will also affect the experience of duration of that interval: an increase in the number of intervals occurring within a given interval, or an increase in the complexity of these events, or a reduction in the efficiency in the way events are coded and stored, would each lengthen the experience of duration of that interval. As Ornstein conclusively observes: "We then *create* our own duration experience from our memories" (Ornstein, 1969, p. 110).

Ornstein's storage size model has its own limits, as Ornstein himself admits. It accounts primarily for one mode of time experience, duration, and cannot be used to account for all the other modes of experiential time (irreversibility, continuity, simultaneity, and so on). Moreover, even as far as the pure experience of duration is concerned, his model does not always hold.

Firstly, it accounts only for one kind of duration judgment: retrospective duration judgments (that is, when subjects do not know in advance that they will later be asked to judge the duration of a time period). It cannot account for what is found when the opposite paradigm is used: prospective duration judgments (that is, when subjects do know in advance that they will later be asked to judge the duration of a time period). While Ornstein's model predicts that an increase in the number of stimuli occurring within a given interval lengthens the experience of duration of that interval, experiments in which subjects are required to make prospective judgments show that the experience of duration shortens when more information is processed. In a typical experiment on duration judgment (Hicks, Miller and Kinsbourne, 1976, Hicks et al., 1977), subjects were asked to

prospectively judge the duration of the time period in which they had to perform a certain task: sorting a stack of playing cards following the instructions the experimenter had given to them. The instructions required that subjects allocated resources to processing non-durational information according to three different levels of increasing difficulty: in the 0-bit condition, subjects were told to hold the cards face up and deal the cards into a single stack as fast as possible during the interval to be judged; in the 1-bit condition, they were told to deal the cards into two stacks, one for red and one for black, as fast as possible; in the 2-bit condition, they were told to deal the cards into four stacks on the basis of suit. The experiment showed that judged time decreased linearly with the increased processing demands of the non-durational information. Therefore, experiments using the prospective time paradigm, in which subjects must not only judge the duration of a time period but also perform a concurrent task occurring during the same interval, or process non-durational information about stimuli during the interval to be estimated, show that perceived time generally contracts as a function of the amount of non-durational information to be processed, or the difficulty of the concurrent task (see also Block and Zakay, 2001, Brown, 1985, Zakay and Tsal, 1989).

Secondly, Ornstein's model cannot even account for all the factors influencing retrospective duration judgments, that is, precisely the kind of duration judgment for which the storage size model was explicitly developed. As Block and Zakay observe (Block, 1990, Block and Zakay, 2001), people do not simply base retrospective duration judgments on the degree of recallability of events from the time period: some other factors are involved as well. For example, people do not attempt to retrieve *all* available memories from the time period: instead they probably rely on an availability heuristic by means of which they remember a duration as being longer to the extent that they can easily retrieve *some* of the events that occurred during the time period. Another factor that strongly influences retrospective duration judgments is contextual changes. Block and Reed (1978) found that people judged a time period as being longer in duration to the extent that there were greater process context changes: a finding this that cannot be easily handled by the storage size model.

Thirdly, the storage-size model is seriously flawed by the fact that it is based on an implausible metaphor of memory as a process running in a digital computer. As Block observes (Block, 1990, p. 23): "Compared to memory processes in digital computers, human memory functions in a more interconnected way, reflecting a continual reorganization of previously encoded information".

Apart from these undeniable limits, Ornstein's work has at least two important merits. The first, is that of having clearly evidenced and stressed the perfidious influences that the internal-clock model brings to bear on the study of mind and human cognition: the adoption of the internal-clock model, implying the idea of or belief in the existence of an external time, independent of ourselves,

unjustifiably minimizes the function and importance of mental processes in producing and forming the experience of time, and consequently distracts researchers' attention from duly investigating and taking them into consideration. Ornstein's second merit is that of having contrived some of the experiments by means of which it is possible to empirically ascertain the role and level of involvement of mental processes in building the subjective experience of time.

2.3.2.2 Attention-based models

As we have seen, experiments on duration judgments in which subjects were asked to prospectively judge the duration of the time period in which they had to perform a certain task, revealed that judged time decreased linearly with the increased processing demands of the non-durational information, and that experienced duration increases to the extent that subjects could allocate more attentional resources to the flow of time itself (Brown,1985, Hicks, Miller and Kinsbourne, 1976, Hicks et al., 1977, Coull et al., 2004). In short, a heightened awareness of the passage of time itself produces a lengthening of the experienced duration. As William James observed:

> Tracts of time (…) shorten *in passing* whenever we are so fully occupied with their content as not to note the actual time itself. A day full of excitement, with no pause, is said to pass 'ere we know it'. On the contrary, a day full of waiting, of unsatisfied desire for change, will seem a small eternity. (…) It comes about whenever, from the relative emptiness of content of a tract of time, we grow attentive to the passage of the time itself (James, 1890, Vol. I, p. 626).

Thus, a prospective duration judgment can be assimilated and considered equivalent to a dual-task condition in which attention must be divided between temporal and non-temporal information processing (Block and Zakay, 2001, Zakay and Block, 2004). For this reason, some theorists have proposed an attention-based model to explain prospective duration judgements or experienced duration. According to Thomas' model (Thomas & Brown, 1974, Thomas & Weaver, 1975), for example, in prospective duration judgments, subjects are faced with a dual task in which they have to share their attention between temporal and non-temporal processing. As non-temporal task demands increase, less attentional capacity is allocated to temporal processing, and duration judgment become less reliable.

The attentional-gate model proposed by Block and Zakay (Block and Zakay, 1996, Zakay and Block, 1997) is an evolved and more refined version of the models previously designed within the internal-clock paradigm (such as, for example, the pacemaker-accumulator clock or the model proposed by the "scalar expectancy theory", sketched in Fig. 3). It contains not only the same modules as those characterizing the previous models, such as a pacemaker, a switch, an accumulator or counter, a memory system, and a comparator, but also an attentional source and an

attentional gate; moreover, it accounts for the possibility that the pacemaker increases the number of produced pulses per unit of time with higher levels of arousal.

According to the attentional-gate model, a subject can divide his or her attentional resources between a temporal task and a non-temporal task. Attending to the temporal task opens the attentional gate, allowing pulses produced by the pacemaker to pass to the counter. Compared to traditional attentional models (such as Thomas's, for example), the attentional-gate model accounts for the facts that:

i) prospective judgments depend not only on the amount of attention allocated to time, but also on the arousal level. Traditional attentional models, assuming a constant pool of attentional resources, cannot explain why reproduced durations (that is, durations estimated by means of the method of reproduction, in which subjects are asked to delimit a second time period corresponding to the their previous experience of the duration to be estimated) are shorter when the duration to be estimated (or target duration) is filled with events (e.g., the flickering of a bulb) occurring at a slower rate (e.g., 0.5 flashes per sec.: slow external tempo) than when it is filled with events occurring at a higher rate (e.g., 2 flashes per sec.: fast external tempo). On the contrary, the phenomenon can easily be explained if one assumes that the faster external tempo leads to increased arousal. Indeed, increasing arousal level leads the pacemaker to produce more pulses per unit of time, making the subject reproduce lengthened durations with increased external tempo. The attentional-gate model, incorporating the notion of arousal, and linking the working of the pacemaker to the arousal level, can account for the phenomenon;
ii) prospective reproductions are typically shorter than target durations. While traditional attentional models cannot explain this phenomenon either, the attentional-gate model is able to account for it. According to the attentional-gate model, during a reproduction all attentional resources are allocated to timing: the gate is opened more widely than during the target duration, when attention is divided between timing and a concurrent non-temporal task. Therefore, during the reproduction, the pulse stream transmitted through the gate is greater than it is during target duration. A reproduction ends when a match is achieved between the current pulse count and the count representing the target duration. The wider gate during the reproduction means that this match occurs after a shorter duration than the duration during which the target count is accumulated.

Evidence supporting the hypothesis that prospective duration judgments can be considered equivalent to divided-attention tasks also comes from studies that show how attentional resources can be allocated to processing temporal information not only implicitly, by modifying the difficulty

of the secondary task as in Hicks, Miller and Kinsbourne's experiment (1976), but also explicitly, by prior instruction on how much attention to allocate for non-temporal stimulus features and how much to allocate for temporal features (Macar, Grondin and Casini, 1994, Zakay, 1998). Zakay (1998), for example, using a primary-secondary task paradigm, showed that the magnitude of prospective duration judgments increased when subjects were told that the temporal task was the primary task and that a simultaneous non-temporal task was the secondary task.

In my opinion, the main problem with attention-based models, as they have been designed up until now, lies in the circularity intrinsic to their main statement: that in prospective duration judgments experienced duration increases to the extent that more attentional resources are allocated to the *flow of time itself*. Attention-based models explain temporal experience by resorting to the very notion of time. For them, the experience of duration depends on, and is determined by, the amount of attention allocated to *time itself*: which is tantamount to explaining one of the dimensions of time, duration, by means of time itself. By pointing out the circularity intrinsic to their main statement, I do not intend to claim that they did not make any contribution to expanding our knowledge of the phenomenology of temporal experience: I believe, on the contrary, that they certainly contributed to empirically confirming what psychologists like James had only intuited, giving full details of the circumstances that bring about the phenomenon. What I intend to say is that their proposal adds nothing to the explanation of where our experiences of time and duration come from, and which mechanisms are responsible for their production: they simply describe, albeit in a very articulated way, the circumstances that alter and condition our perception of time and duration.

Even Block and Zakay's attentional-gate model (Block and Zakay, 1996), although it additionally and explicitly indicates and specifies to which kind of information a person could attend when he or she focuses on time itself (i.e., the pulses produced by the pacemaker), eventually resorts to a sort of internal-clock, which, like all internal-clocks, presents not only the drawbacks Block (1990, 2003) himself recognizes, but also those other inconsistencies and inconveniences I highlighted above. Incidentally, it must be noticed that the alternative, pacemaker-free explanation Block puts forward in (Block, 2003) regarding prospective duration judgments, also does not seem to be completely free from circularity. Block (2003) proposes a memory-age model of prospective duration timing, which should be a plausible alternative to internal-clock models. The memory-age model resorts to the notion of "distance-based processes". Distance-based processes are those that involve judging the recency of an event in a way that is influenced by changes in the characteristics of memories, such as declines in vividness, elaborateness or accessibility of memories. Plainly speaking, according to a distance-based explanation, an event is recent if its memory is clear, while

it is judged to be old if its memory is dim. Researchers usually contrast distance-based processes with "location-based processes" (for a review of the two kinds of processes, see Friedman, 2001): the latter let us judge the recency of an event by retrieving whatever information is associated with it in memory, and relating this information to our rich store of knowledge about personal, natural, or social time patterns. While distance-based processes involve a judgment of the vividness of the memory for the event, and are based on the subject's capacity to have and rely on some impressions of the ages of the events, location-based processes involve inferences about other events in which the event was embedded. The difference between distance-based processes and location-based processes can be better understood if we consider the phenomena of "scale effects": a person may be quite accurate in dating an event as having occurred during a particular time of day (an evaluation based on location-based information), but quite inaccurate in remembering the day, month or year during which the event occurred (an evaluation based on distance-based information). Evidence would seem to suggest that both distance- and location-based processes can be explained by resorting only to normal memory and cognitive processes, without any need to assume separate internal-clock mechanisms. According to Block (2003), prospective duration timing could be based on distance-based information, that is, on the apparent age of events. More precisely: "interval timing involves comparing *apparent ages* of events" (Block, 2003, p. 49; italics are mine) and: "every act of attending to time involves retrieval of information concerning *the apparent age* of the previous act of attending to time" (Block, 2003, p. 50; italics are mine). As one can easily see, the main hypothesis on which Block bases his explanation of ongoing duration timing in humans, that is, that human beings have the capacity to have, and rely on, their own impressions of the ages of the events, does not explain time experience at all, but simply *describes* and *presupposes* it. Indeed, in Block's explanation, human beings' capacity to estimate duration is based on their capacity to have impressions of the *ages* of the events: a notion, this of "ages", which patently already contains in itself the experience of time. Nor does the hypothesis that human beings' capacity to have impressions of the ages of the events would be based on the capacity to perceive changes in the characteristics of memories (such as declines in vividness, elaborateness or accessibility of memories), seem to offer a better solution to the conundrum of subjective time experience. We can have very clear memories of events which occurred a long time ago, or even in our infancy, and yet be unable to remember what we ate yesterday: however, the latter event does not seem to us to have occurred earlier than the former. Not always can the vividness or accessibility of memories account for their ages.

Lastly, as far as the general validity and applicability of attentional-based models is concerned, it must be noticed that their predictions do not hold in those circumstances characterized by shocking

or unexpected events. When facing shocking or unexpected events, subjects' prospective duration judgments are not always consistent with the predictions of the attention-based model: sometimes, contrary to what the attention-based models expect, subjects tend to *overestimate* the duration of shocking stimuli or stimuli requiring more attentional resources. For example, in a work by Angrilli et al. (1997), which had the main purpose of studying the influence of stimulus-induced emotional "arousal" and "affective" valence on the estimation of temporal intervals spent passively attending to the stimulus itself, subjects had to prospectively estimate the duration of a series of slides showing images belonging to four different categories defined by the intersection between the valence dimension (two levels: negative emotions vs. positive emotions) and the arousal dimension (two levels: low vs. high). Angrilli et al. collected heart rate, as an index of attention, and skin conductance responses, as an index of arousal, in order to measure the attentional processing and the arousal processing during the time processing period. Angrilli et al. found that: a) negative slides, regardless of the arousal level, elicited a stronger orienting reaction from the subjects: which suggests that more attention was paid to negative slides than to positive slides; b) time perception during presentation of *low* arousal material was consistent with the predictions of attention-based models (according to which the duration of an interesting or complex stimulus is underestimated because the information processing of the stimulus requires a larger amount of attentional resources): positive low-arousal slides (such as: dog pets or happy babies), inducing less information processing, were relatively overestimated, whereas negative low-arousal slides (such as: big spiders or rats in the dirt), inducing a larger amount of information processing, were relatively underestimated; c) however, time perception during presentation of *high* arousal material was not consistent with attention-based models: negative high-arousal slides (such as: dead cut bodies or babies with eye tumour), inducing a stronger attentional response, were overestimated compared with positive high-arousal slides (such as: naked couples or erotic couples), inducing a weaker attentional response. The high arousal trend, then, conflicts with the attention-based model. Angrilli et al. concluded that their findings testify for: "a double mechanism triggered by arousal levels: an attention-driven mechanism at low arousal levels, clearly consistent with attentional models, and an emotion-driven mechanism at high arousal levels" (Angrilli et al., 1997, p. 979).

Likewise, Tse et al. (2004) found that when a series of stimuli, each lasting the same objective duration, are shown in succession, subjects tend to report that the low-probability oddball stimulus in the series lasts subjectively longer than the high-probability stimulus. Assuming that observers orient or attend to a low-probability stimulus more than they do to a high-probability stimulus, Tse et al. conclude that this phenomenon, which they name *time's subjective expansion* (TSE), is due to the fact that: "the engagement of attention by un unexpected event (…) may actually increase the

rate of information processing brought to bear on a stimulus" (Tse et al., 2004, p. 1184). Their hypothesis that TSE is really due to an attentional effect is supported by the additional findings (experiments 1B, 2, and 4) that: a) the expansion of perceived duration occurs only for objective durations above ~ 120 msec., but not for objective durations below this value: which reflects data showing that at least 120-150 msec. are required before attention can be fully allocated to a new detected stimulus (Nakayama and Mackeben, 1989); b) the curve of the temporal expansion factor (temporal expansion factor = standard time / Point of Subjective Equality of oddball) for stimuli of different objective durations reflects the data showing that attention has two components, one transient, or exogenous, and one sustained, or endogenous. These two attentional components have different temporal dynamics: once attention is fully allocated to the stimulus, a transient component of attention peaks within approximately 100 msec. As the transient component weakens, a sustained component of attention comes to dominate that does not fade as rapidly (Nakayama and Mackeben, 1989); c) the basic pattern of results are found for both visual stimuli and auditory ones, which suggests that the mechanism underlying TSE is a central process, just as attention.

Summarizing Tse et al.'s findings, and Angrilli et al.'s findings: subjects, when facing an unexpected or shocking stimulus A, pay a higher level of attention to it than when facing a neutral stimulus B; despite what is predicted by attention-based models, they perceive the more attended stimulus A as lasting longer than the less attended stimulus B that lasts the same objective duration as A (see also Flaherty, 1999). The findings show, then, that subjects' behaviour during prospective duration judgments does not follow the homogeneous, consistent pattern hypothesized by attentional-based models.

2.3.3 Physical time and psychological time

One of the main sources of circularity in studies of time is the bias towards considering time as a real, ontological entity existing in itself, independently of anything else. This bias is certainly well expressed by Newton's conception of time as a physical, absolute entity, which "flows equably without relation to anything external". The belief in an absolute, real time makes people explain any possible manifestation and aspect of time by referring it to that original, absolute, real time. Unavoidably, this implies giving up any attempt at defining time in positive, non-circular terms, that is, independently of itself. In fact, any manifestation and aspect of time, whether it refers to a subjective experience of duration, to an objective occurrence, or to something else, is reduced to, and explained by, the absolute, real time, which in turn, being "original" and "real", can be explained only through itself, in a self-referential way.

Psychology has not been immune to the bias towards considering time as a real, ontological entity. Many psychologists have been led, for example, to explain psychological, phenomenal time in terms of an absolute, Newtonian, physical time, and, consequently, to believe that phenomenal time has to be analyzed in terms of, and reduced to, the physical time of physiological processes. This stance entails not only an inevitable circularity when the definition and explanation of time is involved, but also some other kinds of drawbacks. We have already seen some of them when dealing with Ornstein's criticism of the internal-clock model (Ornstein, 1969). Some others were highlighted by psychological experiments on the perception of simultaneousness, succession, and instantaneity, and on time estimation, which revealed the groundlessness of the prejudice about the necessity to treat and analyze phenomenal time in the same way as physical time, and to regard the latter as realer, and more fundamental, than the former.

No doubt, one of the most striking and a counter-intuitive phenomenon is that of *temporal displacement*: given a sequence of very brief stimuli, say a-b-c, it often occurs that subjects perceive a different sequence, say A-C-B. The phenomenon, which had been noticed by astronomers since the early 19th century, was named *Zeitverschiebung*, or temporal displacement, by Wundt, who largely investigated it (Wundt, 1902). Wundt imputed the phenomenon primarily to attention: in fact, he demonstrated that addressing attention to whatever stimulus of the sequence accelerates its elaboration by the subject, thus making the subject perceive it before the other stimuli. Benussi (1913) confuted Wundt's explanation on the basis of the consideration that the stimuli of these experiments are too short and too many to allow attention to move from one to the other. According to Benussi, such brief sequences of stimuli are perceived as temporal Gestalten: temporal displacement is the product of the interaction of the stimuli, and of the salience of some stimuli over the others. The phenomenon was also investigated by Rubin (1949), who devised his experiments by resorting to the gestaltist concept of similarity between stimuli, and showed that temporal displacement can occur not only with different sensory modalities, but also within the same sensory modality. A confirmation of the importance of the Gestalt principles in the production of temporal displacement comes from the experiment of Ladefoged and Broadbent (1960), who showed that a brief noise or click that is randomly inserted in a spoken sentence is usually perceived to occur not so much where it originally occurred as in a position where it does not disturb the comprehension of the sentence (more than half of the subjects perceived the noise or click to occur 250 msec before its actual position).

Vicario (1963, 2005) devised an experiment in the auditory field that combined Benussi's theory with Rubin's methodology. He used triplets of stimuli such as a_1-b-a_2, where a_1 and a_2 are high tones of 1760 and 1568 Hz respectively, and b is a low tone very different from the other two: 82,4

Hz (see Fig. 4a). For tones each lasting 100msec, subjects perceive a succession of high notes followed by a low note (see Fig. 4b). As Vicario observes, it is as if the succession of similar, high notes has "expelled" the different, low note, relegating it to a position where it cannot disturb the succession.

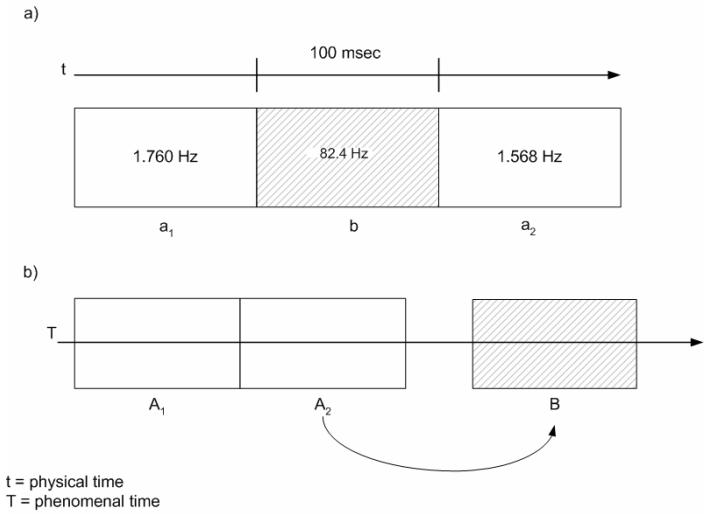

Fig. 4. Vicario's experiment on temporal displacement

Vicario observed that:

a) The displacement of the central note takes place only when stimuli are sufficiently short. For stimuli longer than 150msec, the sequence of notes perceived by subjects tends to correspond to the sequence of the physical stimuli; when stimuli are shorter than 150msec, subjects tend to perceive the central note as displaced. According to Vicario, this finding supports Stern's hypothesis about the existence of the *Präsenzzeit*, or "phenomenal present", that is, the interval of physical time that, despite being composed of non-contemporaneous parts, is perceived as a unitary and unique act of consciousness (Stern, 1897). The temporal displacement takes place only if the sequence of physical stimuli occurs within this interval; if the sequence of stimuli occurs outside the "phenomenal present", the temporal displacement does not take place.
b) With short stimuli of equal length, the probability that the temporal displacement occurs grows with the growing of the tonal distance between the central note and the lateral ones.

On the whole, the experiments on temporal displacement clearly show that: a) a non-temporal characteristic, such as the qualitative difference of pitch between tones (low vs. high), determines a temporal characteristic (perceiving a stimulus as occurring after or before another stimulus); b)

phenomenal time does not correspond, and cannot be reduced, to physical time: the former can be neither explained, nor understood in terms of the latter. Phenomenal time also depends upon principles of organization, such as the Gestalt ones, that do not hold true for physical time: short, succeeding stimuli are perceived not so much as separated and isolated items following one another, but as parts of a whole, where the characteristics of the single items (i.e., being perceived as coming after or before) are determined by the global structure comprising them.

The difference between phenomenal time and physical time was also confirmed by another experiment carried out by one of Vicario's collaborators (Trasforini, 1996). In the experiment, subjects had to identify the temporal position of a very short stimulus (a white noise pulse of 50 msec) inserted in a sequence of two relatively longer stimuli (two pure tones) lasting either 1 sec or 200 msec. The identification was done in two ways: 1) with a simple reaction task, in which subjects had to push a button as soon as they heard the white noise pulse; 2) with an estimation task, in which subjects, after having heard the whole sequence of stimuli, estimated the position of the white noise pulse by marking it on a 10 cm line representing the sequence of the two pure tones. The results show that while in the simple reaction task, subjects identify the white noise pulse almost exactly, in the estimation task they regularly displace in time the white noise pulse. The different results of the experiment can be roughly explained by the different nature of the two tasks: while the reaction task can be considered essentially as a *physical task* (pushing a button), where the perceptual activity of the subjects is confined to its basic and simplest form (hearing the white noise pulse), the estimation task calls for more sophisticated and advanced *perceptual and cognitive capacities*. In fact, in order to identify the position of the white noise pulse, subjects have to consciously compare the sound they are perceiving (that of the white noise pulse, if the second pure tone has already started, or that of the second pure tone, if the white noise pulse has occurred during the first pure tone) with a sound they perceived before (that of the second pure tone, or that of the white noise pulse, respectively). Moreover, the latter is not as "fresh" as the former, and subjects have to use their short-term memory to perform the comparison. In the estimation task, therefore, the temporal relations between the stimuli are determined not so much by pure physical conditions (as is the case, on the contrary, in the reaction task) as by psychological factors, such as Gestalt principles governing perceptual grouping of stimuli. This explains the presence of temporal displacement in the evaluation task and the absence of temporal displacement in the reaction task.

An even more astonishing piece of evidence corroborating Vicario's observation that phenomenal time is not the same as, and cannot be reduced to, physical time is provided by the phenomenon of *continuous displacement* (Italian: "dislocazione continua"), or *stream segregation*, described in Bozzi and Vicario (1960). When subjects listen to a sequence of stimuli composed of

the four tones shown in Fig. 5a that repeats cyclically, they will hear a single sequence of low and high sounds if each stimulus lasts about 200msec (Fig. 5b), and *two different synchronized sequences* of sounds (a low trill and a high one) if each stimulus lasts about 50msec (Fig. 5c).

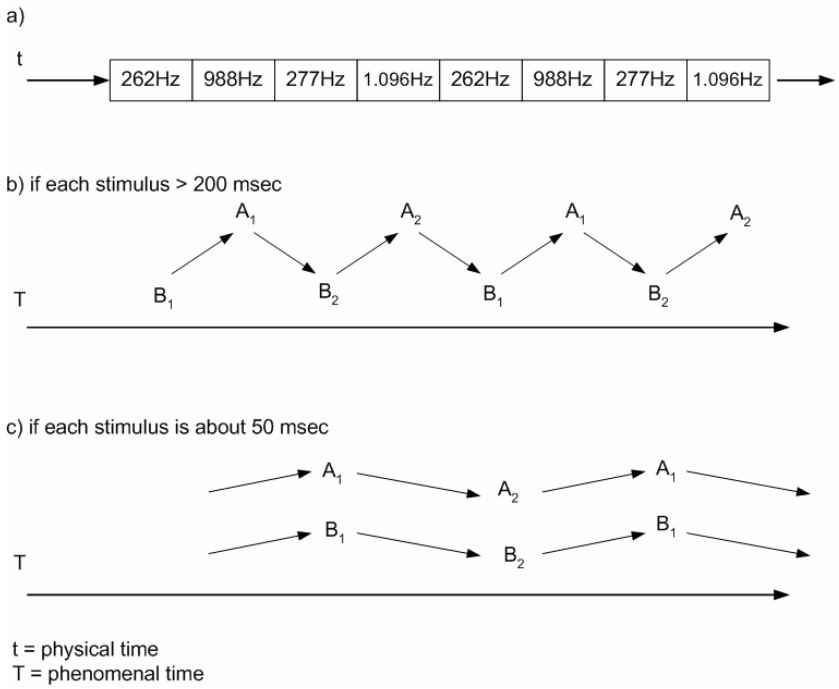

Fig. 5. Bozzi's and Vicario's experiment on continuous displacement

The fact that the phenomenon of continuous displacement occurs only when stimuli are sufficiently short, about 50msec, is for Vicario another piece of evidence for the existence of the "phenomenal present" hypothesized by Stern:

Se le singole fasi di un evento cadono tutte in quell'ambito di tempo fisico che venne definito da Stern come "tempo di presenza psichico" (…) possono verificarsi casi di ristrutturazione della sequenza degli stimoli, in virtù per l'appunto di fattori diversi dalla contiguità temporale, per esempio a causa della *vicinanza nello spazio tonale*. Se invece le singole fasi di un evento occupano un intero "presente fenomenico", non è più possibile alcuna ristrutturazione nella sequenza degli stimoli, cui corrisponde perfettamente la successione delle fasi percepite (Vicario, 2005, p. 130).

(I translate into English: "If all the single phases of an event fall into that interval of physical time that Stern defined as *Präsenzzeit*, the sequence can undergo some kind of restructuring irrespective of the physical temporal contiguity of the stimuli, such as that determined, for example, by the proximity of the stimuli in the tonal space. If, on the contrary, the single phases of an event occupy a whole *phenomenal present*, the sequence of stimuli cannot undergo any kind of restructuring, and the sequence of the perceived stimuli will correspond to the sequence of the physical stimuli").

According to Vicario, the phenomenon of continuous displacement, which can also be observed in visual experiments (Vicario, 1965), can be classified as a case of *double representation*: a single

physical (whether spatial or temporal) event or object gives rise to the perception of two different, but simultaneous events or objects. A paradigmatic example of double representation is the well-known cross of Fuchs-Metzeger. Double representation can be explained as an adaptive advantage that allows the human being to perceive contemporaneously two different things from a single point of observation without spending additional energy or time.

The experiments on temporal displacements and, even more so, those on continuous displacement inflict a fatal blow on any theory that conceives of phenomenal time as an internal, subjective, and distorted copy, duplicate or representation of a purer, realer and more original form of time: the external, objective time of physics. What the psychological observation and analysis of perception reveals is that the order of perceived events does not correspond, and is sometimes in contradiction, to the order of physical events: what is "before" in phenomenal, subjective time can be "after" in physical time, and vice versa; what is perceived as contemporaneous or simultaneous in phenomenal time, can be a sequence of events in physical time.

Moreover, while in physical time simultaneousness excludes succession – A cannot be simultaneous with B, and, at the same time, occurs before B -, in phenomenal time the former does not exclude the latter, and vice versa. Indeed, when certain conditions are given, for instance, with sufficiently short stimuli, we can have the sensation that some events that are non-simultaneous nevertheless are also non-successive, and vice versa. From perceived simultaneousness to perceived succession there exist various intermediate perceptual possibilities: heterogeneity, discontinuity, apparent movement; events can be perceived as "floating" in an undefined space, etc. (Vicario, 2005, p. 116).

What holds for simultaneousness and succession also holds for continuity and discontinuity. Events that at the physical level are discontinuous can be perceived at the phenomenal level as continuous: As the phenomena described by Vicario (2005) show – the "tunnel effect", the "Renard effect", the perception of stopping, the "window effect", the stroboscopic movement -, a physical discontinuity is perceived as a phenomenal continuity; an object that has stopped, or that is still, is perceived as moving.

Moreover, the boundary between perceived continuity and perceived discontinuity is not so clear: between the two we can have different and various sensations. If in the realm of physics it is quite easy to distinguish what is continuous from what is not, in the realm of perception continuity and discontinuity represent the two extremities of a series of possibilities: in some cases, the movement of an object can be described, for example, as a compromise of continuity and discontinuity (Vicario, 2005, p. 66).

Similar discrepancies between the realm of physics and the realm of phenomenal experience can also be observed for:

a) Space and velocity, and for the relationship between space, time and velocity. As Vicario (2005, p. 215) states, the relationship between perceived space, perceived time, and perceived velocity is not the same as the relationship between physical space, physical time and physical velocity;
b) Cause and effect. As the "window effect" shows, as well as the "phi phenomenon", the causal theory of time, according to which a cause of a certain effect always precedes in time the effect, and, in turn, the effect always follows in time its cause, while being always valid in the realm of physics is not always valid in the realm of perception. In the realm of perception causes may lie not so much in the past as in the future. The usual relationship between what comes "before" and what comes "after" of the time of physics is sometimes overturned in perception.

Vicario observes that the idea that phenomenal time must be treated as, and assimilated to, physical time, entails not only the impossibility for psychologists to account for the important, surprising and counter-intuitive evidence revealed by experiments on perception, but also the obvious danger that they put forward or look for wrong motivations for this same evidence, thus prejudicing their research.

One of the wrong motivations psychologists put forward for the difference between phenomenal time and physical time is the distortion human beings introduce when perceiving time. The reasoning that leads psychologists to propose this motivation is the following. Human beings would be equipped with a basic mechanism that allows them to convert physical time into phenomenal time – exactly as happens with other kinds of sensations: human beings have eyes to convert electromagnetic waves into colours, nose and mouth to convert chemical substances into smells and tastes, etc. However, both the psychological factors to which human beings are subject, such as past experiences, expectations, and motivations, and the strategies and acquired abilities they use, among which above all the ability to count, distort the conversion of physical time into subjective, phenomenal time. Consequently, if psychologists want to analyze how human beings' basic mechanism dedicated to the conversion of physical time into phenomenal time really works, they should adopt in their experiments all those methodological precautions capable of hindering subjects from using strategies such as counting that could interfere with the basic mechanism, and of preventing psychological factors from occurring.

According to Vicario (2005, p. 173), this really makes an absurd demand of subjects: "Si pretende che il soggetto misuri qualcosa, e gli si vieta l'uso di un'unità di misura" (I translate into

English: "You expect that subjects estimate something, but you forbid them from using any way of measuring it"). Any operation of estimation is always based on the comparison of what has to be estimated with a reference system. In the specific case of the duration of a certain event, subjects estimate it by comparing the duration of the event with the duration of some kind of "internal" activity that subjects implement contemporaneously with the event itself. As also confirmed by Franceschini's experiment (1998), subjects who had been forbidden from counting, used various strategies anyway that allowed them to estimate the duration of an event: some of them used images or sounds as a reference system; some others based themselves on the number of breathes taken; etc. Therefore, it is unreasonable to ask subjects that they do not count or use any similar strategies when estimating duration of the events.

In short, the stance of considering the psychological, phenomenal time as a kind of internal, subjective copy or representation of an external, objective, more basic, and truer form of time - the absolute, Newtonian time of physics – not only represents a source of unavoidable circularity whenever one tries to define and analyze time itself, but also proves to be ineffective when put to the test. It is certainly more preferable and reasonable to conceive of the time of physics as a construction based and developed on the subjective, phenomenal and more fundamental experience we have of time. After all, everything we know is known primarily in and through our conscious experience. First of all, we come to know the world as it is thanks to our direct and subjective conscious experience and observation; only successively can we "abstract" or rationalize our experience, and develop those *entia rationis* that characterize physics as well as the other sciences. As Vicario observes (2005, p. 13): "I termini che si usano in fisica sono quelli che si sono sempre usati nel linguaggio quotidiano, che descrive l'esperienza diretta, quella psicologica" (I translate into English: "The vocabulary of physics derives from everyday language, which describes direct experience, that is, psychological experience").

2.4 Circularity in neurosciences

As we have seen in the previous section, one of the main sources of circularity in studies of time is the bias towards considering time as a real, ontological entity existing in itself, independently of anything else, and permeating everything. This bias involves considering and conceiving of things, objects and events of the world as "necessarily" being, occurring, and plunged in time (as well as in space): they would "naturally" be characterized by the temporal dimension. We would experience time because time permeates and constitutes everything.

Also neuroscientists, as psychologists and linguists, are not always able to escape from such a bias. Sometimes they explain our capacity to discriminate intervals and durations, recognize speech, coordinate movements and actions, play the piano, and so on, in a word, to process time, by resorting to notions such as the "rhythms" of our cerebral cortex, the "oscillations" of neurons, and the like (see for example, Churchland and Sejnowski, 1992): that is, notions that already contain time in themselves as one of their fundamental components. According to this kind of explanation, we can process time in its various manifestations because we are provided with mechanisms (neurons, cell-assemblies, neural networks, etc.) whose working is inherently and essentially based on time. Time is not simply a product, an outcome of such mechanisms and of their working: it is inherent in them.

However, as we have seen, the idea that experienced time reflects a more "fundamental", objective form of time – the absolute time of physics - raises more problems than solutions. There are too many and too blatant differences and inconsistencies between phenomenal time and physical time in need of a plausible and satisfactory explanation and reconciliation. Moreover, as Dennett and Kinsbourne (1992) have shown, there is no need at all to postulate a sort of isomorphism between the neural level and the psychophysical level in order to explain phenomenal time. Phenomena such as the "colour phi" or the "cutaneous rabbit" clearly show that phenomenal time, what Dennett and Kinsbourne call the "representation of time by brain processes", is not always based on "time-in-the-brain", that is, the actual sequence of events making up those brain processes. Using Dennett and Kinsbourne's terms, one must distinguish between "time represented" and "time of representing".

The limitedness and uselessness in conceiving of our capacity to process time as the expression of brain mechanisms and structures that would be *inherently* temporal is further highlighted by the impressive difference of scales and types of temporal processing characterizing human beings' behavior. On the one hand, we are able to quite flexibly estimate intervals ranging from a fraction of a second to some minutes and to hours, which helps us sense how long we can lounge in bed after the alarm clock goes off, or how fast we have to run to catch a baseball. The brain circuitry that allows us to mark time spans seems to involve a loop from the cortex to the striatum to the thalamus and back to the cortex again: it is so powerful and flexible that, according to Warren H. Meck, it can learn the time stamp for every interval one can imagine (Wright, 2006).

On the other hand, we are also provided with a mechanism, involving the suprachiasmatic nucleus, that serves to synchronize quite accurately bodily functions with the cycles of sunlight and darkness. They help to program the daily habit of sleeping at night and waking in the morning, they drive daily fluctuations in blood pressure, body temperature and other core rhythms. But some other

mechanisms exist as well that tune the other bodily functions to some other external cues, such as stress, temperature changes and exercise (Wright, 2006).

The variety of tasks and behaviors that rely on temporal processing is so wide (they range from simple sensory tasks, such as interval, duration and motion discrimination; to complex forms of sensory processing, such as speech recognition; to motor tasks, such as playing the piano; and to daily and seasonal rhythms, such as appetite and sleep and wake cycles) and the brain areas potentially involved (basal ganglia, cerebellum, cortex) are so many and different that it is practically impossible to identify in and through them the common principle, mechanism or substratum on which time experience lies. Everything – whether it be neurons, cell assemblies, the cerebellum, the cerebral cortex, or something else - being intrinsically temporal and working on a temporal basis, time is nowhere.

Realizing this, some neuroscientists prefer to abandon a pure locationalist approach in favor of an information processing approach. For example, Mauk and Buonomano go so far as to propose that: "temporal processing does not rely on specialized mechanisms, such as oscillators, or arrays of elements, as with a spectrum of different time constants. Rather, we believe that neural circuits are inherently capable of processing temporal information as a result of state-dependent changes in network dynamics" (Mauk and Buonomano, 2004, p. 334) (see also Eagleman et al, 2005, p. 10370: "the way the network evolves through time can code for time itself"): which represents in my opinion, above all as regards their reference to the "changes" undergone by the system, a first, though partial, step toward solving the puzzle of time experience. Equally interesting and full of promising implications, even though to be yet attentively considered and examined, is their supposition that: "temporal and spatial information are generally processed together by the same circuits" (Mauk and Buonomano, 2004, p. 334) (on this point see also the work by Wyss et al., 2002 and 2003, who put forward the hypothesis that visual patterns, that is, spatial representations, are made possible by and through temporal encoding).

3. A way out of circularity: the proposal of Attentional Semantics

A suggestion about how to escape circularity in general, that is, regardless of the context and the specificity of the field of research, comes from semantic studies, and precisely from a specific kind of semantics: Attentional Semantics (Marchetti, 2003, 2005, and 2006). The proposal of Attentional Semantics to get out of circularity consists in considering words and their meanings in terms of the end they serve, and the means and processes developed and implemented in order to achieve the end.

As we have seen, in the definition of the meaning of a certain word, circularity is very often occasioned by the use of concepts, ideas, notions and words that, directly or indirectly, derive from the meaning under definition: that is, when one defines the meaning of a certain word by resorting to elements that are not independent of that word, and whose existence is partially or completely due to it. This way of defining the meanings of words is tantamount to defining or explaining the purpose or *raison d'être* of a given instrument or device (say a ruler) by means of the occasional, particular measures you obtain time by time when making measurements with it (for instance: 10,5m, 201cm, 1,56km, etc.). It is obvious that such a kind of explanation can neither account for all the possible measurements you can make with the device, nor justify its existence, and that, if anything, it is the specific measures which should be accounted for by the device. The ruler does not exist in order to make those occasional, particular measurements (10,5m, 201cm) but to make measurements in general and more precisely to make linear measurements. If you want to explain the *raison d'être* of a device you have to take into account and mention: a) the theory, notions and aims that lie beneath and behind it, and on which and for which the device was developed and built, (in the case of the ruler, the Euclidean geometry, the notion of linear length, the idea that linear length can be measured, etc.); b) the techniques, processes and procedures used to build the device.

Incidentally, it has to be noticed that if you accepted the idea that a device can be explained by resorting to the occasional uses and applications you make time by time, you should also clarify why only some of its uses can account for its existence, while others cannot: a ruler for example can be used also to make a fire, or to play, but obviously these kinds of uses cannot account for it. This fact unavoidably would lead you to leave out altogether all the occasional, particular measures, and focus on the general ideas of measure and measurements.

Likewise, if you want to explain the whys and the wherefores of words and of their meanings, you have to consider not so much the specific outcomes their use and application can occasionally produce (such as, for example, the emerging and appearing of new ideas, concepts, words or ways of seeing things, resulting from the combination of certain words), as the general end and objective they serve and for which they were originally developed. By looking for their general end, you will not fall into the trap of defining them on the basis of the occasional, individual results deriving from their use (and misuse), but you will focus on the original and fundamental grounds which motivate both their use and existence, and on which their use is made possible. This in turn will lead you to analyze the context in which the end developed, the needs the end satisfies, what processes and operations have to be performed in order to achieve the end, and what kind of mechanism implements these processes. Consequently, you will be forced to perform your analysis of words no

longer at the same level as that characterizing words themselves, that is, the linguistic one, but at other, non-linguistic levels of explanation. Circularity will thus be avoided.

As I have said, the suggestion by Attentional Semantics of considering the end for which words and their meanings were originally developed can be of help in escaping circularity not only in linguistics but also, more in general, in any other field of research. After all, in order to describe and analyze phenomena, scientists have to use words (or symbols, which anyway express meanings, albeit in a more precise and definite way than words). And when one uses words to explain something, one should be aware of the bulk of implicit knowledge that any language unavoidably brings with it. This kind of implicit knowledge makes us take for granted and assume the existence, universality and certainty of the meanings, presuppositions, beliefs, ideas, concepts, and categories that were shaped, elaborated and maintained by the specific culture or society in which a specific language was developed. When scientists define and explain phenomena, they use in their definitions and explanations words that incorporate and include such a bulk of implicit knowledge, with all its meanings, presuppositions, beliefs, concepts, etc. Therefore, when trying to analyze and describe phenomena, scientists have to face a double cause or source of circularity: on the one hand, the tacit knowledge they usually bring with themselves, a tacit knowledge which derives from their own personal abilities, experiences and observations, and which any one usually carries with oneself during one's own life; on the other hand, the implicit knowledge inherited from the language they use. The implicit knowledge inherited from the language scientists use, favors the occurring of circularity in scientific explanations and definitions. In fact, this implicit knowledge sometimes makes scientists unconsciously adopt in their explanations and definitions meanings, concepts, ideas and categories that derive from and were built on precisely those phenomena scientists have to explain, define and prove. Because of this, it may then happen that sometimes scientists' definitions and explanations do not really define anything, and that they simply beg the question, repeating tautologically what should be defined and explained. Obviously, being aware of the latent existence of such a kind of implicit knowledge in language should help scientists avoid circularity.

What is then the main end of words? Why has humankind developed such a tool? In my opinion, *the main end of words is that of indicating to, and eliciting in, the listener or reader a specific conscious experience: namely, the conscious experience referred to by their meanings.* Each word elicits one or more conscious experiences that differ from the conscious experiences elicited by the other words. The conscious experiences elicited by words may concern and refer to as many different and various things such as an object of the world external to us (this is the kind of experience conveyed for example by words like "table" and "sun"), an animal ("cat"), ourselves

("I"), an activity ("to work"), an instruction on how to combine our conscious experiences and to relate conscious experiences to each other ("and", "or", "of", "by"), a product of our imagination ("dragon"), and so on.

Most probably, each culture and society developed and selected during its own history those words and meanings that proved to be most useful for the survival, maintenance, control and development of the society itself (and sometimes also for the suppression of some other society). Each language embodies the knowledge attained by a certain society, and is the result of the evolutionary process undergone by the society itself. Each single word of a language represents and indicates a specific object, activity, event or entity elaborated and produced within and for a specific society and culture (and sometimes against a specific society and culture). Each society develops and maintains that language and system of words that best fit the society's interests: using von Glasersfeld's terms (1985), we could say that only those words that are most *viable* and function satisfactorily for a given society can emerge and survive.

The conscious experience elicited by the meanings of words is not the same as the conscious experience elicited by images, memories or perceptions: the former differs from the latter in that it lacks the qualitative properties of the latter. Moreover, while meanings refer to a whole class of objects or events, images, memories and perceptions do not: the word "cat", for instance, refers generally to all kinds of cats, regardless of their colour, sex, age, and so on; on the contrary, an image of a cat specifies its colour, shape, etc.

How do words succeed in eliciting in the reader or listener the conscious experience referred to by their meanings? What means do they exploit in order to achieve this end? On which processes they rely?

According to Attentional Semantics, the meanings of words isolate, de-contextualize, "freeze" and classify in an articulated system the ever changing and multiform stream of our conscious experiences. Each meaning is composed of the sequence of invariable elements that, independently of any individual occurrence of a given conscious experience, are responsible for the production of any instance of that conscious experience. As I tried to show elsewhere (Marchetti, 2003, 2005, and 2006), *the elements that compose the meanings of words and are responsible for the production of the conscious experiences referred to by the meanings are attentional operations*. The main tenets of Attentional Semantics are the following ones:

a) Conscious experience, in general, is the product of attentional activity: attentional activity can be performed thanks to a special kind of energy, nervous energy, which is supplied by the organ of attention; when we perform attentional activity, we use our nervous energy; attentional activity

directly affects the organ of attention, causing a variation in the state of nervous energy; it is this variation that constitutes the phenomenal aspect of consciousness;
b) Each word conveys the condensed instructions on the attentional operations one has to perform if one wants to consciously experience what is expressed through and by it. Words accomplish the task of eliciting in the listener or reader the conscious experiences referred to by their meanings, by having the listener or reader perform the attentional operations they convey.

Attentional Semantics aims explicitly at finding the attentional instruction conveyed by the meanings of words, that is, the sequence of attentional operations that one has to perform if one wants to consciously experience what the meanings of words express. To achieve this goal, Attentional Semantics tries:

1. firstly, to identify the sequence of the essential, elementary conscious experiences that invariably accompany, characterize, and are prompted by, the use of the word being analyzed;
2. secondly, to describe these conscious experiences in terms of the attentional operations that are responsible for their production;
3. thirdly, to identify the possible unconscious or non-conscious operations serving either as the support that makes it possible for the attentional operations to take place and to be completed, or for them to occur in a certain way, or as the necessary complement that makes it possible to execute and implement the activities determined and triggered by earlier conscious experiences.

As one can see, the proposal of Attentional Semantics of identifying the specific end the meanings of words serve, and the processes necessary to achieve the end, represents a plausible a-linguistic counterpart of language, and an effective way out of circularity.

It has to be noticed that a word may have one or more meanings associated with it. Apart from the cases of pure and real homonymy, the different meanings that may be associated with a word are related to each other. This fact is better accounted for by such an approach as the "principled polysemy approach" put forward by Evans (2004) than by a "homonymy approach" or a "monosemy approach". Indeed, while the principled polysemy approach claims that a word such as *time* has more, different, but anyway related, meanings associated with it, the "homonymy approach" admits that a lexical form can have different meanings associated with it, but that they constitute a bundle of completely distinct, unrelated senses that merely by accident happen to be associated with the same lexical form, and the "monosemy approach" holds that a lexical form is paired only with a highly abstract sense, and that the various meanings that sometimes happen to be

associated with that lexical form would simply be explained in terms of contextually derived variants of the single monosemous abstract sense.

According to Evans (2004), the homonymy approach cannot account for the fundamental fact, well attested by etymological and philological studies, that language constitutes an evolving system in which: a) the meanings associated with words may not only undergo changes in time, but also, through a process of metaphorical extension, give birth to new meanings; b) these new meanings, despite being different from the original ones, remain associated to the lexical form to which the original meanings were associated, instead of being associated to new lexical forms. By overlooking this evidence, the homonymy approach fails then to consider the fact that there must be some degree of commonality and relatedness between the yet distinct original and extended meanings associated with a given word. In fact, if the meanings associated with a given word were completely distinct and unrelated to each other, there should be no reason why they remained associated with the same original lexical form rather than being associated with completely new lexical forms.

The monosemy approach, on the contrary, fails to recognize that a word such as *time* has a number of different meanings associated with it that are demonstrably context-independent, and is unable to account for the fact that the context cannot always be invoked in order to explain differences in interpretation and distinctions of meaning. Furthermore, the monosemy approach cannot account for all those words whose meanings, despite stemming from the same historically earlier sense (what Evans would call the origination sense), designate as distinct and different entities as a physical object and a mental entity. The word "volume", for example, identifies both a physical object, that is, a book, and an abstract entity more akin to a pure mental entity than to a physical object, that is, the amount of space in a container or occupied by a substance. As Benedetti argues (Benedetti, 2001), the monosemy approach cannot account for the difference existing between the literal[2] or original meaning of a word and the meanings derived from its extended or figurative uses. That the original meaning differs from and is not the same as the extended or figurative ones is supported by a body of evidence: a) the appearance of an extended or figurative meaning is so recent that it can easily be documented: only quite recently from an historical point of view has a word such as "left" begun to designate a specific political party; b) the humorous use by comics of the different meanings of a word (included the extended or figurative ones) to produce puns or ironic or comical effects; c) the fact that while a given language has developed extended or figurative meanings of a given word, another language has not: for instance, while the Italian

[2] While the concept of "literal" may sometimes prove to be ambiguous and problematic in linguistics (cfr. Ariel, 2002), I think that most of the time it is nonetheless useful because it allows us to distinguish somehow what a native speaker feels to be the basic and usual meaning of a word from its extended or figurative meanings.

language has developed an extended meaning of the verb "mangiare" ("to eat") to indicate gaining possession of a chesspiece, the English language has not; d) some words, especially adjectives, while being perfectly synonymic in their extended or figurative use, are not so in their literal use: for example, the Italian adjectives "piccola" ("little", "small"), "leggera" ("light"), "debole" ("weak", "feeble"), "poca" ("little"), "scarsa" ("poor", "short"), and "bassa" ("low", "short") are interchangeable when used in their extended or figurative sense, as when they are used in association with a word designating a pure mental content, such as "differenza" ("difference"), while they are not synonyms when used in their literal sense, as when they are used in association with a word designating a physical object; e) usually, there is wide agreement between dictionary compilers on the existence of figurative or extended meanings that are different from the literal one.

4. The conscious experience of time explained: Mach's revised hypothesis

Therefore, in order to avoid circularity when analyzing the meanings of words, we have first of all to ask ourselves: "What are the elementary conscious experiences that they invariably elicit in us?". The identification of the elementary and invariable conscious experiences produced by the meanings of words can be performed thanks to the fact that any conscious experience implies the possibility of being distinguished and differentiated from the other ones. Indeed, this is one of the most important characteristics of conscious experience (although it is not peculiar only to conscious processes): allowing us to distinguish things and differentiate an object from the others. It is the conscious experience of the meaning of a given word that makes us differentiate it from the meanings of other words. In analyzing (some of) the meanings of the word "time", I will rely mainly on this method.

4.1 Time and space: a comparison

As we have seen when dealing with Evans' work (Evans, 2004), more than one meaning can be identified in the case of the word "time". Let us consider the meaning referring to the subjective experience of time, that is, what Evans holds to be the "sanctioning" meaning associated with the lexical item *time*: the durational meaning. Here are some sentences by means of which Evans exemplifies the durational meaning of the lexical item *time*: "The relationship lasted a long/short time"; "It was some/a short/a long time ago that they met"; "During their ill-fated marriage they fought a lot/some/much of the time"; "He returned to Germany for good in 1857, moving for a time to Berlin"; "Time flies (by) when you're having fun"; "Time crawls (by) when you're bored".

What distinguishes the subjective experience of time from the conscious experience elicited, for example, by a word which is usually contrasted with time, that is, "space"? In my opinion, these are the main differences between the subjective experience of time and the conscious experience of space:

i) firstly, while time has only one dimension, space has more than one. This makes us perceive things in space as given all at once, catching them all - as it were - with only one glance; and makes us perceive things in time as occurring only in succession;
ii) secondly, subjective time is irreversible, whereas space is not. We can walk back and forth over the same path more than one time, but we cannot go back to the past and live again the same moments, hours or days we lived; what is present now will become past, and the temporal order of events cannot be reversed. The irreversibility of some very important and vital processes clearly shows the directionality of experienced time. From a phenomenological point of view, time can only be experienced as irreversible. Even if it is possible to conceive of time as a reversible process, as sometimes physicists do, the sole way we can experience time is, as Vicario (2005) has observed, as something running on toward only one direction. If we witnessed a cold cup of coffee that somehow and unexpectedly warms up all on its own, or an old man who becomes younger, certainly we would report the inverted, unusual order of events. However we could not report that our subjective time has stopped running on, and that it has inverted its course, now starting going back: actually, we would continue experiencing our subjective time as something proceeding forward, in the same direction toward which it used to go before. Moreover, it is precisely because of the fact that, despite witnessing such strange and unusual phenomena, we would not experience any difference in the course of time that we could speak of events occurring in the reverse order. In the end, the succession of events would certainly seem illogical, unusual, and inverted, but our experience of the past, present and future, of the before and the after, would not change. The irreversibility of experienced time constitutes then one of the most important and unquestionable certainties we have about time.
iii) thirdly, space is stationary, time is not. Time flows on, in an unstoppable way, whereas space is still. Most probably, it is the association of these characteristics with the characteristics described at point i) that makes us have the different sensations described in Ceccato and Zonta's quoted passage (Ceccato & Zonta, 1980) when considering objects from a spatial point of view and from a temporal one.
iv) fourthly, time-sensations are more "abstract", intangible in nature (that is, determined by inner processes) than space-sensations, which are more concrete, tangible, and visible: that is, time-

> sensations can be considered to be more akin to sensations like pain, pleasure, thirst, huger, sexual desire, and tiredness, and to psychological states such as emotions, moods, and impulses, than to sensations such as colours, sounds, tastes, smells and movements. Most probably, this can be explained by the fact that space-sensations are more strictly and directly linked to and determined by our exteroceptive and proprioceptive organs than time–sensations, which on the contrary seem to be linked to and determined by our interoceptive organs (Marchetti, 2006).

Incidentally, it must be noticed that this last kind of difference between space and time is at the base of the fact that we ordinarily use language pertaining to motion through three-dimensional space and locations in three-dimensional space in order to think and talk about time. As highlighted by Evans (2004), there is a fundamental bifurcation in the conceptual system between concepts of sensorimotor, i.e., external origin, such as those which relate to visual-spatial experiences and are symbolised by the words like "near" and "motion", and concepts of subjective, internal origin, such as "time" and "similarity". According to Evans, concepts of external origin are a result of the elaboration in conceptual terms of visual-spatial information, or "inter-subjective information"; concepts of subjective origin are a result of the elaboration in cognitive terms of internal states, or "subjective-information" (Evans, 2004, p. 34). While inter-subjective information is quite easily elaborated in conceptual terms, and consequently encoded and "translated" in linguistic terms, subjective information is difficult to conceptualize and verbalise. Indeed, it is easier to talk about what we perceive out in space than to talk about the states of our body or about what we feel. An instance of the difficulty of directly verbalising subjective information is given by the experience of time: in fact, we ordinarily think and talk about time not in time's own terms, but rather in terms of motion through, and location in, three-dimensional space, as evidenced by sentences such as "We are getting close to Christmas" or "The deadline is approaching" (on this point, see also Lakoff and Johnson, 1999, Talmy, 2000). As Jackendoff has suggested (Jackendoff, 1992), our relatively poor ability to verbalise internal states compared to our relatively good ability to articulate external information, may be due to a lack of sufficient "hardwiring" between the body format, which encodes subjective information pertaining to internal states, and the conceptual format, which provides information in a form ready for linguistic encoding, compared to the strong connection between the visual or 3D format, which encodes visual-spatial information from the external world, that is, inter-subjective information, and the conceptual format. It is highly plausible that the human brain has been able to circumvent the lack of "hardwiring" between the body format and the conceptual format by directly connecting the body format to the visual/3 D format. In such a way,

subjective information is elaborated in terms of inter-subjective, external sensory experience, and can therefore more readily and easily enter into focal consciousness and be verbalised.

So much for the differences between space and time. However, there are not only differences, there are also similarities. William James, for example, found that, just as the same objective length of time can be subjectively perceived as either long or short according to the context, age of the perceiver, conditions of perceiving, and so on, exactly a parallel variation occurs in our consciousness of space:

> A road we walk back over, hoping to find at each step an object we have dropped, seems to us longer than when we walked over it the other way. A space we measure by pacing appears longer than one we traverse with no thought of its length. And in general an amount of space attended to in itself leaves with us more impression of spaciousness than one of which we only note the content (James, 1890, Vol. I, p. 627).

Both temporal experience and spatial experience are then characterized by a certain variability compared to objective time and space, that is, time and space measured with physical instruments such as clocks and rulers.

In my opinion, there also exists another important similarity between time and space, strictly linked with the property described at point i): from and on both space and time, it is possible to build the notions of "order", "sequence", and "series". When we perceive objects, we can either perceive them isolated from their environment and the other objects, as it were, in themselves, or perceive them as placed in space or time (or, more specifically and accurately, in their environment, in a context, in a house, in the past, and so on). In the latter case, and only in the latter case, it is possible for us to ascertain whether an object lies "behind" or "in front of" another object, whether it appeared or came "before" or "after" another object, and so on. That is to say, by putting the object in a spatial or temporal dimension, we can create, constitute, and build up an order, a sequence, or a series of objects. Obviously, by putting objects in a spatial dimension, we will characterize them with properties that differ from the properties they assume when put in a temporal dimension: for example, object A cannot occupy the *same space as* that occupied by object B; on the contrary, both objects can exist at the *same time*. Nonetheless, both time and space give equally the same possibility of constituting an order, and arranging objects in sequences and series.

Therefore, basing ourselves on these differences and similarities, it is possible to formulate a hypothesis about what elementary and invariable conscious experiences characterize and constitute the sanctioning meaning of the word "time". We can summarize them with the following list of substantives: *one-dimensionality, irreversibility, unstoppability, impalpability, variability, and orderability*.

4.2 Mach's revisited hypothesis

How can we translate this set of elementary conscious experiences into attentional terms? To what attentional operations does this sequence of conscious experiences correspond?

In my opinion, a very important suggestion comes from Ernst Mach (1890). He argued that it is probable that time-sensation is connected with the organic consumption of our attentional energy: "we feel the *work of attention* as time" (Mach, 1890, p. 111). He arrived at this conclusion by observing that: a) so long as we are conscious, time-sensation is always present, while in dreamless sleep – when our attention is completely exhausted - the sensation of time is lacking; and b) during severe effort of attention time is long to us, during easy employment short: "in phlegmatic conditions, when we scarcely notice our surroundings, the hours pass rapidly away" (Mach, 1890, pp. 111-112). Time-sensation would then be correlated with and conditioned by the "fatiguing of the organ of consciousness", which goes on continually in waking hours, and the labour of attention, which increases just as continually. Consequently: a) "The sensations connected with greater expenditure of attention appear to us to happen *later*" (Mach, 1890, p. 112); b) "it is intelligible why physiological time is *not reversible* but moves only in one direction. As long as we are in the waking state consumption and the labour of attention can only increase, not diminish" (Mach, 1980, p. 115).

As we see, then, Mach relies on attention to account for some of the main experiences associated with time:

1) irreversibility and one-dimensionality: "If time-sensation is conditioned by progressive organic consumption or by the corresponding steady increase of the effort following upon attention, then it is intelligible why physiological time is *not reversible* but moves only in one direction" (Mach, 1980, pp. 114-115);
2) unstoppability: "The fatiguing of the organ of consciousness goes on continually in waking hours, and the labour of attention increases just as continually" (Mach, 1980, p. 112);
3) variability: "during severe effort of attention time is long to us, during easy employment short" (Mach, 1980, p. 111);
4) orderability: "The sensations connected with greater expenditure of attention appear to us to happen *later*" (Mach, 1890, p. 112).

However, on the face of the results of research adopting the prospective paradigm (Bloch and Zakay, 2001, Brown, 1985, Hicks et al., 1976), Mach's hypothesis obviously needs to be slightly

modified as far as the phenomena of variability is concerned. As we have seen in the preceding paragraphs, abundant evidence shows that the degree to which attention is directed to the flow of time itself greatly affects the experience of duration: prospective time judgements increase as a result of decreased attention to non-temporal processing. Situations involving a heightened temporal awareness, such as impatience, anticipation and expectation, produce a lengthening or slowing down of time; in contrast, concurrent situations involving absorbing activities that distract the subject from processing time produce shortened durations (Flaherty, 1999). As Tse et al. observe, "Attention increases duration judgements when duration per se is attended" (Tse et al., 2004, p. 1172).

As these findings show, therefore, what determines the sensation of duration would be not so much the total labour (or expenditure) of attention in general (as instead Mach's hypothesis seems to imply), nor *only* the specific labour of attention necessary to perform a certain activity or perceive a certain event (if it were so, the activities requiring a great expenditure of attention would *always* entail an expansion of the perceived time: which however is precisely what the findings on prospective duration judgment confute), as the labour of that portion of attention dedicated to the estimation of the duration of a given activity, event or interval: the more attention we pay to estimating the duration of a given event or interval, the longer the event or interval seems to last.

Therefore, if we complement Mach's hypothesis with the findings resulting from research adopting the prospective paradigm, we can explain the experience of duration in the following way, which we can name "Mach's revised hypothesis":

a) we devote a certain portion of our attention (let us call it A_e) to a certain kind of activity, which we call the "non-temporal processing", that is, the event or activity whose duration we have to estimate;
b) we devote another portion of our attention (let us call it A_t) to another kind of activity, which we name "temporal processing";
c) the activity of A_t consists in being associated with A_e, in the sense of: i) being focused on the conscious product of the activity performed by means of A_e, and ii) staying focused on such a product, keeping present at each new act of focalization also the results of the previous focalizations, in a continuous and incremental way;
d) A_t is independent of, and does not correspond with A_e, in the sense that despite drawing resources from the same limited pool, A_t and A_e are – at least, to a certain extent - separate and independent streams of attention;

e) the labour of A_t, A_t being associated with A_e, increases continually and proportionally with the labour of A_e;

f) however, A_t, drawing resources from the same limited pool as A_e, is unavoidably affected by the labour of A_e, so much so that an excessive increase of labour of A_e entails a decrease or slowing down of labour of A_t, (as the experiments using the prospective time paradigm show, time generally contracts as a function of the amount of non-durational information to be processed, or the difficulty of the concurrent task);

g) it is the continuous increase in the labour of A_t that constitutes the basis for any temporal estimation: it represents the cue we use to determine the elapsed time. The amount of labour performed by A_t *is* the time elapsed. More in general, it is this continuous increase in the labour of A_t that represents the basis on which human beings have built their notion of time;

h) since, as we have seen, attentional activity produces conscious experience, also in the case of the activity performed by A_t we have a conscious outcome: the conscious experience of the elapsed time.

Compared to Mach's original hypothesis, then, the revised version allows one also to account for the findings on prospective duration judgments: when the event whose duration has to be estimated needs too much A_e to perform the non-temporal task, A_t undergoes a slowing down.

As one can see, Mach's revised hypothesis rests on some important assumptions, some of which were also empirically verified. Firstly, attention is considered as a limited general purpose resource which can be flexibly allocated from moment to moment according to the subject's needs, goals and motivations (Kahneman, 1973, Lavie, 1995). Secondly, attention can, to a certain extent, be divided between a number of activities: as evidenced by divided-attention studies, when the total load of stimulus processing does not exceed a certain threshold, subjects are able to process information arriving on more than one channel at a time (Pashler, 1998). Thirdly, attention is a cyclical phenomenon, a repetition of successive acts of focalization, and each attentional cycle or act of focalization has a certain minimal and maximal duration. This fact has not only been theorized and experimentally tested (Large and Jones, 1999, Ward, 2003), but can also be easily personally ascertained: as William James claimed, no one can possibly attend continuously to an object that does not change. Moreover , given the tight correlation between attention and conscious experience – as Mack and Rock (1998) have extensively shown with their work on the phenomenon of inattentional blindness, there cannot be consciousness without attention -, the cyclical nature of attention can be inferred, more in general, from all those conscious phenomena characterized by discreteness (for a review, see Fingelkurts and Fingelkurts, 2006), such as for example the

consistent correlation, found by Varela et al. (1981), between the perception of apparent simultaneity and the alpha phase at which stimuli are presented. Fourthly, the results of the previous acts of focalization can, to a certain extent, be kept present in consciousness while new acts of focalization occur. When rehearsing a given string of numbers or letters, for example, a telephone number, we can, also thanks to short term memory, be conscious not only of the rehearsed item, but also of some of the immediately preceding or following items. There is however a limit in this capacity of keeping present simultaneously more than one item. In fact, when dealing with very simple perceptual items (that is, involving low level of processing demand), we can keep simultaneously present in consciousness only some of them, i.e., from three to four or five at maximum: we cannot keep as many items as we want. Therefore, in order to keep trace of longer sequences, there must be some additional mechanism, such as chunking, capable of organizing, "synthesizing" and treating as a single unit the groups of three/four items (Miller, 1956).

4.3 Attending to time is perceiving the effort made by the organ of attention

Mach's revised hypothesis, linking time-sensation with the quantity of labour performed by A_t, implicitly entails the possibility of monitoring and determining such a quantity. Without such a possibility, one could not estimate how much labour A_t has performed. This possibility relies entirely on the capacity we have to directly perceive *the effort* the organ of attention makes while performing a certain activity. The capacity to directly perceive the effort made by our organs in general is an innate one: it is precisely this capacity which gives us the possibility of feeling the fatigue of our various organs, and of having sensations of exhaustion, weariness, tiredness, freshness, etc. In the case of the organ of attention, the perception of the effort made by it derives from the continuous, incremental and cumulative working of A_t. As we have seen, when we want to experience the duration of a certain event, we devote a certain part of our attention, A_t, to the temporal task, associating it to the conscious product of the activity performed by another portion of attention (A_e), which is necessary to perceive, bring about, etc. the event. A_t has to remain focused on the product of the activity performed by means of A_e, as long as the activity takes place; furthermore, and most importantly, A_t has to keep present the results of its continuous work, that is, at each new act of focalization it has to keep present, in an incremental way, the results of the previous focalizations. Keeping present the results of its continuous work while performing its successive acts of focalization, obviously entails for the organ of attention an additional, cumulative effort. As we have seen, attentional activity in general is made possible thanks to the nervous energy supplied by the organ of attention: therefore devoting a certain part of our attention (A_t) to a

certain kind of task (a temporal one) implies devoting a certain portion of the nervous energy supplied by the organ of attention to that task. Since the temporal task requires that A_t performs an incremental work, the expenditure of the nervous energy supplied by the organ of attention will have an analogous incremental trend. At the beginning of the event whose duration we want to experience, the work performed by A_t is minimum and the expenditure of the nervous energy (supplied by the organ of attention) dedicated to the temporal task is similarly minimum. At the end of the event, the work performed by A_t is maximum and the expenditure of the nervous energy similarly maximum. While low amounts of expended nervous energy entail low sensations of effort, high amounts of expended nervous energy correspond to high sensations of effort. The final amount of the expended nervous energy devoted to the temporal task represents the total effort that the organ of attention has made to support the activity of A_t. This effort constitutes and determines the basis on which the conscious experience of duration and time-sensation more in general are built.

When a specific duration judgment is required - instead of the bare, general sense of time-in-passing -, some additional organs different from the organ of attention are involved. In the case of a duration judgment, at least a long term memory and a comparator are needed: the former, to store the knowledge about personal, natural, or social time patterns; the latter, to compare the subjective sensation of fatigue ensuing from the activity of A_t with the knowledge about time patterns stored in memory.

We see then how the conscious experience of time is made possible by attentional operations, which in turn are based on physical organs and unconscious and non-conscious processes.

While the idea that time-sensation derives, specifically, from perceiving the changes (namely, the effort made by the organ of attention) entailed by the activity of *attention* is - with the only exception of Mach, and in part of James, as far as I know - relatively new, the idea that time-sensation is, in general, somehow linked to the capacity to perceive *changes* is not new.

As we have already seen, for example, for Lakoff and Johnson: “Literal time is a matter of event comparison” (Lakoff and Johnson, 1999, p. 139). According to William James, not only time sensations but also space sensations rely on an awareness of change:

> In short, empty our minds as we may, some form of *changing process* remains for us to feel, and cannot be expelled. And along with the sense of the process and its rhythm goes the sense of the length of time it lasts. Awareness of *change* is thus the condition on which our perception of time’s flow depends (…) The change must be of some concrete sort – an outward or inward sensible series, or a process of attention or volition. And here again we have an analogy with space. The earliest form of distinct space-perception is undoubtedly that of a movement over some one of our sensitive surfaces, and this movement is originally given as a simple whole of feeling (James, 1890, Vol. I, p. 621).

Mach himself believed that time is an abstraction, at which we arrive by means of the changes of things (Mach, 1883). Fraisse stated that: “psychological duration is composed of psychological

changes" (Fraisse, 1963, p. 216). Gibson maintained that: "external stimuli (…) provide a flow of change, and it is this we perceive rather than a flow of time as such" (Gibson, 1975, p. 299). Block stated that: "attending to the passage of time means attending to changes in cognitive context – that is, certain aspects of the contents of consciousness" (Block, 1979, p. 195).

Moreover, it has to be noticed that by relying on the very notion of change, some psychologists have developed part of their theories and research on time. Let us consider, for example, the work on retrospective duration judgments (or remembered duration) by Block, Reed and Zakay (Block, 1990, Block and Reed, 1978, Block and Zakay, 2001, 2003, Zakay and Block, 2004). Contrary to what Ornstein proposed with his storage-size model (Ornstein, 1969), Block and Reed (1978) found that changes in cognitive context have a more important influence on retrospective duration judgments than does the number of stored events: "the greater are the encoded and retrievable contextual changes, the longer is the remembered duration of a time period" (Block, 1990, p. 25). Contextual changes may occur as a result of variation in background stimuli, interoceptive stimuli (e.g., posture, temperature, etc.), the psychological context (e.g., what the subject is thinking about), the processing context (e.g., the different kinds of cognitive strategies adopted by a subject during a given task), and the environmental context. According to Block and Reed, remembered duration involves a cognitive reconstruction based on retrieving not so much stimulus information per se, as Ornstein hypothesized, as contextual information that was stored as an integral part of the memory encodings of events. People apparently encode automatically contextual information as an integral part of their memory representations of events, and use it whenever they are requested to make retrospective duration judgments.

People rely on contextual information to make not only retrospective duration judgments, but also temporal order, temporal dating and recency judgments. Evidence is given by experiments that show that people are quite accurate in dating an event as having occurred during a particular time of day, but are considerably inaccurate in remembering the day, month or year during which the event occurred (Friedman and Wilkins, 1985). According to Friedman (1993, 2001), such a kind of phenomena – called "scale effects" – highlights the fact that people judge the recency of an event basing themselves on important contextual landmarks, rather than on a more absolute way, such as in terms of time tags or the strength or vividness of a memory trace: that is, they rely on "location-based processes" rather than on "distance-based processes". Block and Zakay conclude: "In short, people automatically encode contextual information concerning experienced events, a process that does not require conscious intention. When they later need to make a temporal order or recency judgment, they rely on whatever information is available in memory to reflect the temporal dimension, and they use contextual information and logical inferences based on it" (Block and

Zakay, 2001, p. 61). Evidence that people encode automatically contextual information concerning experienced events is given, for example, by the fact that they can make rather accurate temporal judgments without being previously forewarned that they will be requested to do so.

The hypothesis that people remember a time period as being longer in duration to the extent that there were greater context changes – called the "contextual-change model" – predicts, contrary to Ornstein's storage-size model, a positive time-order effect in retrospective duration judgments, that is, the fact that subjects remember the first of two equal time periods as being longer than the second. Indeed, according to the contextual-change model, a subject encodes greater contextual changes during a more novel experience, such as during the first of a series of several durations, than during the following durations. Evidence supporting the prediction of the contextual-change model show that the positive time-order effect is eliminated if the environmental context prevailing during the second of two durations is different from that prevailing during the first (Block, 1982), and if changes in emotional context that would ordinarily occur during the first duration occur instead during a preceding time period (Block, 1986).

The work by Block and Zakay seems also to reveal a double dissociation between retrospective duration judgments and prospective duration judgments: if a subject must change the way he or she processes information, retrospective duration increases, but prospective duration is not affected. On the contrary, non-durational information-processing difficulty, while greatly affecting prospective duration judgments, has little or no influence on retrospective duration judgments. Empirical findings revealing the double dissociation were obtained in regard not only to non-executive functions and information-processing tasks (Block and Reed, 1978, Block and Zakay, 1996), but also to executive-control functions and tasks (Zakay and Block, 2004), that is, those involving the regulatory processes supervising the translation of intentions into a goal-directed behaviour and controlling and governing its conduct.

In one of their experiments, for example, Block and Zakay (2004) had their subjects resolve syntactic ambiguities, that is, reading sentences that have several possible syntactic analyses (such as the sentence: "The horse galloped fast after the race his legs always shiver". The ambiguity of the sentence is due to the omission of the full stop, which can create different meanings if it is put after "fast" or after "race"). Resolving syntactic ambiguities requires that subjects, at least, compute the multiple interpretations of the sentence, choose the more likely syntactic interpretation on the basis of the context and relative frequency of occurrence, discard the alternative interpretations, and mark that point in their representation of the sentence as a choice point. All these operations clearly indicate that resolving syntactic ambiguity involves executive-control functions such as initiating memory search, inhibiting responses, encoding high-level structures in memory, etc. In this

experiment, each subject was randomly assigned to one of four experimental conditions formed by the orthogonal combination of temporal paradigm (retrospective vs. prospective) and reading task (syntactic ambiguity vs. no-syntactic ambiguity). Upon completing the reading, subjects were asked to reproduce the reading duration and rate the degree of mental load they experienced while performing the reading task. While in the prospective condition subjects were told that after the reading was completed they would be asked to reproduce the total reading duration, in the retrospective condition, subjects were not. Actual reading duration was measured for each subject without his or her knowledge.

The results were the following: a) actual reading duration was significantly longer if there was syntactic ambiguity than if there was no syntactic ambiguity; b) ratings of mental load were significantly higher if there was syntactic ambiguity than if there was no syntactic ambiguity; c) if there was no syntactic ambiguity, prospective reproductions were significantly longer than retrospective reproductions; on the contrary, if there was syntactic ambiguity, retrospective reproductions were significantly longer than prospective reproductions; d) if there was no syntactic ambiguity, the duration-judgment ratio, that is, the ratio of the reproduced duration to the actual reading duration, was significantly longer in the prospective paradigm than in the retrospective paradigm; on the contrary, if there was syntactic ambiguity, the duration-judgment ratio was greater in the retrospective paradigm than in the prospective paradigm.

Overall, the results seem to reveal a double dissociation between prospective and retrospective duration judgments. According to Block and Zakay, this is due to the fact that different cognitive processes underlie prospective and retrospective timing: “The decrease in prospective reproductions in the syntactic ambiguity condition in comparison to the simple reading (no-syntactic ambiguity) condition indicates that resolving syntactic ambiguity is a process that consumes attentional resources. The increase in retrospective reproductions in the syntactic ambiguity condition in comparison to the non-syntactic ambiguity condition indicates that resolving syntactic ambiguity is a process that produces contextual changes that are encoded in memory” (Block and Zakay, 2004, pp. 323-324).

Without doubt, as far as retrospective duration judgments are concerned, Block, Reed and Zakay’s work represents an important improvement compared to Ornstein’s (Ornstein, 1969). Indeed, the former shows that not all kinds of information are equally useful for the purpose of estimating the duration of a past interval, as instead the latter claimed: when judging a past interval, we specifically rely more on the contextual changes that occurred during the interval, than, for example, on stimulus complexity.

However, I think that the conclusion they reach concerning the double dissociation between prospective and retrospective duration judgments is not correct. I do not think that, in order to estimate duration in the two different paradigms (prospective and retrospective) we use two different processes (attention and memory, respectively). I think that the means by which we estimate duration remains always the same, and that it is attention to time. There are at least two reasons that lead me to think this:

a) Firstly, from an evolutionist point of view, it seems really implausible that in order to perform the same activity (estimating time) an organism had to develop two different systems and processes.
b) Secondly, it is certainly true that in the retrospective condition we have to resort to memory. However, it must be noticed that resorting to memory means *paying attention* to the material stored in memory: that is, performing a certain "non-temporal" attentional activity (A_e) in order to consciously experience the stored material again. Indeed, when estimating past events, it is as if we lived them again, even if for a short period. We can then hypothesise that, excluding the cases in which we estimate the duration of a past event by resorting to the original experience of duration we could have actually had when the event occurred, in all the other cases we estimate the duration of a past event by allocating part of our attention (A_t) to this purpose, focusing it on the conscious product of the activity performed by means of A_e and perceiving the effort made by the organ of attention while the event is consciously remembered. Two things must be noticed: i) In the retrospective condition, once the event whose duration we have to estimate has been retrieved from memory, it is fully available to us and we have to make no additional effort to produce it again while we are processing time. This implies that in the retrospective condition, unlike what happens in the prospective one, temporal processing is determined and affected not so much by the amount of attention (A_e) used to process non-temporal information, as by the amount of available (contextual) "clues" that can be used to anchor and deploy A_t. The greater the number of available clues, the higher are the possibilities we have to anchor and deploy A_t, the longer is the remembered duration of a time period. Therefore the retrospective situation can be assimilated to a prospective situation in which we are allowed to allocate the greatest part of our attention to the temporal information task rather than to the non-temporal information task. Being allowed to pay almost our whole attention only to the estimation of the duration of the event, we experience an expansion of time that is directly proportional to the amount of (contextual) information retrieved from memory: which reconciles Block and Zakay's finding on retrospective duration judgments with Mach's revised hypothesis. ii) In the retrospective

condition we cannot use the same parameters as in the prospective ones: an event that actually lasted an entire day may be consciously remembered and synthesized in a few seconds. Therefore, the amount of labour performed by attention while the event is remembered, must be adapted and parametrized as much as possible to the real, original situation.

Moreover, there is also evidence suggesting that the double dissociation between prospective and retrospective duration judgments hypothesized by Block and Zakay does not always hold. As we have seen when considering the work by Angrilli et al. (1997) and by Tse et al. (2004), subjects' behaviour during prospective duration judgments does not follow the homogeneous, consistent pattern hypothesized by attentional-based models. Unlike what attentional-based models predict, when facing shocking or unexpected events subjects tend to *overestimate* the duration of stimuli requiring more attentional resources. In such cases, contrasting subjects' behaviour during prospective duration judgment with subjects' behaviour during retrospective duration judgment does not produce the double dissociation found by Block and Zakay.

Incidentally, how can we explain the findings by Angrilli et al. (1997) and by Tse et al. (2004) by using Mach's revised hypothesis?

As we have seen, Angrilli et al. (1997) found, contrary to what attentional-based models predict, that negative high-arousal stimuli, inducing a stronger attentional response, were overestimated compared with positive high-arousal stimuli, inducing a weaker attentional response. Psychological evidence suggests (for a review, see Kahneman, 1973) that, to a certain extent, higher levels of arousal enhance the capacity of processing stimuli: that is to say, stimuli can be processed faster and deeper at high levels of arousal than they are at low levels of arousal. This implies that, at higher levels of arousal, less attention is needed to process stimuli than is usually required, or alternatively, that stimuli are processed at lower or marginal levels of attention. Also psychophysiological and neurophysiological studies show that emotionally arousing stimuli are processed in a very quick, automatic way as compared to neutral stimuli. For example, Öhman and Soares (1994) found unconscious pre-attentional responses to phobic masked stimuli lasting only 30 msec in subjects that reported no awareness of the content of the stimuli. According to LeDoux (1995), two different pathways are responsible for the emotional stimulus processing: one subcortical, which is quickly activated by potentially dangerous stimuli, but receives only incomplete information, and one cortical, which is slower, but processes more precise information on the nature of the stimuli. The subcortical pathway can rapidly activate physiological autonomic responses for avoidance and fear-related behaviours, which is certainly in line with a biologically adaptive function. The very fast,

unconscious processing of emotionally arousing stimuli makes stimuli almost completely available to us without requiring from us any specific conscious activity to bring them forth.

Therefore, stimuli becoming almost fully available with little or only marginal attention, we can dedicate the greatest part of our attention to the temporal task (even though it must be noticed that: a) when facing emotionally arousing stimuli, we also devote some amount of our energy to the maintenance of our attention on them; b) this amount of energy increases proportionally with the negative quality of the stimuli: it is easier to maintain one's attention on a pleasant image than on an unpleasant one). Paying almost all our attention to the temporal task, we consequently experience an expansion of time. Just as in retrospective conditions, so in prospective conditions entailing high levels of arousal, temporal processing is determined not so much by the amount of attention (A_e) used to process non-temporal information, as by the amount of "clues", made available by the unconscious processing, that can be used to anchor and deploy A_t. Negative stimuli, entailing because of their content more clues than positive stimuli, induce a higher deployment and expenditure of A_t compared to positive stimuli: consequently, negative stimuli are overestimated compared with positive ones.

As to Tse et al.'s experiments (2004), which showed that low-probability oddball stimuli are judged to last subjectively longer than high-probability stimuli lasting the same objective duration as low-probability ones, two different but concurrent factors must be taken account. Firstly, high-probability stimuli facilitate and induce habituation and automatic processing: which implies that less attention (A_e) is needed to perceive high-probability stimuli compared to low-probability stimuli. Consequently, A_t being focused on the conscious product of the activity performed by means of A_e, less A_t is expended for high-probability stimuli than for low-probability stimuli. Secondly, it is known that novel and odd events tend to capture and engage attention more than usual and normal stimuli. Low-probability oddball stimuli, therefore, tend to consume up more A_e resources than high-probability stimuli, and, consequently, to proportionally entail a higher expenditure of A_t compared to low-probability ones.

4.4 The economical nature of "Mach's revised hypothesis"

As we have seen, "Mach's revised hypothesis" is able to account for empirical evidence resulting from research carried out in both the prospective paradigm and the retrospective one. Contrary to what Block and Zakay claim, it is not necessary to resort to two different kinds of processes in order to account for prospective and retrospective timing.

But this is not the only advantage "Mach's revised hypothesis" offers; indeed, it offers some other important ones. Firstly, it does not imply any dedicated internal-clock or pacemaker mechanism. This fact entails a double advantage. On the one hand, it avoids all the epistemological, theoretical and methodological problems raised by the internal-clock model, which we have seen in the previous sections. On the other hand, it relies only on a very basic component such as attention that is used also for other and different purposes, without needing to resort to additional components, such as a pacemaker. Incidentally, it must be noticed that the choice of relying on a pacemaker would imply the additional problem of identifying *the plausible* pacemaker: as shown by Mauk and Buonomano (2004), the impressive difference of scales and types of temporal processing characterizing human beings' timed responses and behavior makes implausible any hypothesis about specialized and dedicated mechanisms such as oscillators, pacemakers and the like.

Secondly, contrary to what Ornstein maintained ("The different times of experience will require different types of explanation. A theory which might account for the experience of simultaneity might not handle the experience of duration", Ornstein, 1969, p. 109), "Mach's revised hypothesis" proves to be very economical: it can cover the various and diverse aspects of phenomenal time in a way that was unknown to the other models and theories. As we have already seen, it can account for the principle aspects of one-dimensionality, irreversibility, unstoppability, variability, and orderability characterizing the subjective experience of time. But it can also account for some other phenomena, such as:

i) The ability of human beings to *directly* perceive and estimate the duration of events. Human beings experience the passage of time directly, and are able to perceive the difference between a situation in which time is passing by smoothly and effortlessly and one in which time is dragging on. Mach's revised hypothesis, on the one hand, by identifying time-sensation with the effort made by the organ of attention, supplies the basis for explaining (within the theoretical model put forward by Attentional Semantics), from a first-person perspective, how it is possible for us to autonomously build and develop a conscious sense (and subsequently, a notion) for time, basing ourselves completely and only on our own (physical and mental) means; on the other hand, not resorting to any dedicated internal-clock mechanism, Mach's revised hypothesis prevents any possibility of explaining time experience adopting a third-person perspective, that is, by surreptitiously introducing a ready-made, unanalyzed concept (that of time) from the outside into us. Consequently, Mach's revised hypothesis explains time-sensation not so much as an external entity that is imposed on us and that, as such, is and remains unknown to us, but rather as the product of autonomous beings who, by acting, determine and come to directly know

themselves and their environment (on the importance of assuming a first–person perspective in order to analyze conscious beings, see Marchetti, 2001).

ii) The phenomenon known as *prior-entry*: when a person attends to a stimulus, he or she perceives it as having occurred earlier in time than it would if he or she was not attending to it. As we have seen when considering the experience of orderability, Mach's revised hypothesis predicts that the event associated with the lowest amount of labour performed by A_t (that is, the event on which attention is focused first) is the one coming "first" or "before" conversely, the event associated with the highest amount of labour performed by A_t (that is, the event on which attention is focused later) is the one coming "later" or "after". The phenomenon of prior entry has been claimed and attested by many psychologists, such as for instance Wundt and Titchener. Although the empirical evidence for this phenomenon has been questioned on the methodological ground that it could reflect the influence of response biases on the observer's judgement (Pashler, 1998), that is, the fact that observers may be biased to report the event to which they were instructed to attend as having the requisite quality, the latest research, successfully attempting to reduce, if not eliminate entirely, the influence of response biases and other confounding factors, confirms the existence of a robust prior entry effect (Shore et al. 2001, Shore and Spence, 2004). Incidentally, it has to be noticed that the phenomenon of prior entry, which is usually studied by having subjects perceive the temporal order of pairs of stimuli separated by an Inter-Stimulus-Interval (ISI), occurs only when certain conditions are met. For example, outside a certain range of ISI, prior entry does not take place: a pair of stimuli each one 15msec long, separated by an ISI shorter than 40ms, cannot be perceived in succession (Kanabus et al., 2002). With sufficiently longer stimuli, also non-temporal factors intervene, such as the degree of resemblance between the stimuli, causing the phenomena of temporal displacement and continuous displacement so well described and analyzed by Vicario (2005). The temporal limits described in the works of Kanabus et al. (2002), as well as the "phenomenal present" advocated by Vicario (2005), can be taken as further evidence supporting the assumptions I previously made about attention, namely, that: attention is a cyclical phenomenon; each attentional cycle has a certain minimal duration; and attentional cycles represent the building blocks of conscious experience (on this point see also Pöppel, 2004). Events occurring within, or lasting approximately as long as, the minimal duration of an attentional cycle either are not differentiated and discriminated, or undergo some process of restructuring and grouping, according to non-temporal principles of organization, such as the Gestalt ones.

iii) The phenomenon observed by James that, if an impression or event, which we are expecting, and ready for (such as a word in a speech, a note in a piece of music, the bus, etc.), fails to come,

we will become "most formidably aware of the extent of the mere time itself" (James, 1890, Vol. I, p. 626): that is, all those instances which induce us to think about, and perceive the passage of, time even if we did not intend to do so. In my opinion, what happens in these cases is that expecting too much, without being able, as to say, to "close the loop", that is, not perceiving what we expect, engenders a feeling of frustration and discomfort in us. The discomfort is strictly determined by the consumption of the nervous energy used to wait for the impression or event to come. Discomfort, like all kinds of pain, fatigue, and tiredness, automatically compels us to focus on, and monitor its possible cause (so as to be able to solve the cause itself). Since the cause is the very activity performed by ourselves (that is, waiting for something that does not arrive), the additional, secondary activity of repeatedly focusing on the primary activity performed by us (waiting for something that does not arrive) represents the first necessary step to bring about what, in terms of Mach's revised hypothesis, is called A_t: that is, the portion of attention allocated to a temporal task. Indeed, A_t is defined as that portion of attention that is associated in a continuous way to the portion of attention (A_e) necessary to perform a given, "non-temporal" activity. Therefore, waiting for something in vain brings about a secondary activity of attentional focusing, which, being repeatedly performed, constitutes the basis for temporal estimation and, consequently, makes us aware of the passage of time itself. Obviously, if we distract ourselves while waiting for something, for example by reading or speaking with someone else, we will prevent or diminish the possibility of bringing about the phenomenon.

iv) The fact that novel events seem to last longer the first time they are seen than the subsequent times, and the fact that complex and demanding activities seem to last longer the first time they are performed than the subsequent times. Compare, for example, the first time you saw a movie, heard a song, or drove through a place with the second time you saw the same movie, heard the same song or drove through the same place: usually, the second time the event seems to last shorter than the first one. These phenomena can be explained by considering the fact that the first time we performed a certain activity or perceived a certain event, or when the activity we performed was too complex, our *whole* attention was involved in, and absorbed by, the activity or event; on the contrary, the subsequent times we perform the activity or perceive the event, we automatically perform, that is, in a unconscious way, some of the operations that during the first time were under our conscious control, because we have become accustomed to the activity or event: consequently, we do not need to pay as much attention to the activity or event as we did the first time. This implies that when evaluating – either prospectively or retrospectively – the various durations, less A_t is expended in the subsequent times than in the first time, A_t being

associated with the portion of attention (A_e) necessary to perform the activity or perceive the event.

v) The fact that while witnessing unexpected, dangerous or shocking events, even if they are misperceived or false threats, we are induced, firstly, to become aware of the passage of time itself, and secondly to perceive time as slowing down, almost to the point of having stopped. Consider for example one of the many narratives quoted from the interviews collected by Flaherty in his work on the perception of time:

> I was in the bathroom, and I heard someone come up the stairs. I was alone and … I had left the door unlocked because my sister would come in late. I could hear the person come up the stairs because the floor cracked. I … instantly focused on my watch [thinking] I could give it to the maniac so he wouldn't kill me (which was pretty stupid). It seemed like he was coming up those stairs so slowly. I thought it took about fifteen minutes [but] it only took less than a minute. I heard the maniac come toward the bathroom, and I was ready to [offer] my watch for my life. It turned out to be my brother (Flaherty, 1999, p. 56).

If the girl had thought that the person coming up the stairs were not so much a maniac as her brother, certainly she would not have had such an abnormally protracted experience of time. Flaherty notices acutely that: "Subsequent to *The Wild Bunch* by Sam Peckinpah, it has become commonplace for directors to depict violence in their films through slow-motion cinematograph" (Flaherty, 1999, p. 51). As Flaherty observes, what characterizes unexpected, dangerous or shocking events, and brings about the experience of protracted duration, is both a narrowing of the scope of subjects' attention to the immediate circumstances, and a heightening of their attention to their self. I think that while the latter characteristic represents the main factor inducing the experience of time, the former characteristic represents the main factor inducing the experience of a protracted duration as opposed to a compressed one. The heightened attention to the self - which can be due either to the direct involvement of subjects in the situation, and the consequent threat for their personal safety, or to subjects' capacity for sympathy and taking on the role of the other - implies that subjects focus, among other things, on their own attentional activity and the products of such an activity: which is precisely the condition necessary to bring about temporal processing. The narrowing of the scope of subjects' attention to the immediate, potentially dangerous circumstances can be considered a consequence of the fast, unconscious mechanisms that - as we have seen when considering the processing of emotionally arousing stimuli - make potentially dangerous stimuli available to the subject without the need for the subject to perform a dedicated conscious, attentional activity. This automatic, unconscious availability of the dangerous stimuli makes the subject experience the event as slowing down.

5. A semantic analysis of some of the other meanings associated with the word *time*

In the preceding section, we have mainly dealt with the elementary conscious experiences that are invariably elicited by the "sanctioning" meaning associated with the lexical item *time*, that is, the durational meaning; we have also identified the attentional operations responsible for the production of such conscious experiences, and briefly dealt with the physical organs and the unconscious or non-conscious operations that serve as a support that makes it possible for the attentional operations to take place and to be completed.

It must be noticed that the durational sense associated with the lexical item *time* is a rather vague, indefinite and abstract one in comparison with estimations of durations expressed in terms of the intersubjective time of clocks and calendars, such as "two hours", "in an hour", "two weeks", and so on. While in the latter case subjects estimate durations by referring their personal estimations to the time of clocks and calendars, thus trying to translate them into the measuring system of clocks and calendars ("It took me two hours to get there"), in the former case subjects perform their estimation on the basis of their personal, subjective conception of time, which naturally does not entail any reference to an objective, official measure system ("It took me a lot of time to get there").

5.1 The moment sense

An even more abstract sense associated with the lexical item *time* is the "moment sense". As shown by Evans (2004), the moment sense does not prompt for a reading relating to an interval, as instead the duration sense does, but rather to a discrete point: "The time for a decision has arrived/come"; "What size was she at the time of change?"; "What time is it?"; "She could die at any time". That the moment sense is an additional meaning not apparent in the duration sense is corroborated by the concept elaboration criterion. "A moment reading appears to be elaborated solely in terms of deictic motion: that is, motion which presupposes a particular deictic centre with respect to which the motion takes place" (Evans, 2004, p. 124). It is with respect to a specific deictic centre that a temporal moment can come or arrive. The duration sense, on the contrary, is elaborated, especially in its two variants of "protracted duration" and "temporal compression", in terms of the relative rapidity (or otherwise) of the motion event: "Time whizzed/zoomed/flew/sailed/raced/dashed along". Also the grammatical criterion confirms the fact that the moment sense is different from the duration sense: while the latter is a mass noun, the former is a count noun, as evidenced by its

ability to be determined by the indefinite article: "Due to the volatile nature of the market, we left instructions to sell at an appropriate time" (Evans, 2004, pp. 125-126).

Evans puts forward two different motivations for the derivation of the moment sense from the duration sense: a) the first relates to the phenomenon of time embeddedness, that is, the fact that all social acts are temporally fitted inside of larger social acts. As certain events or intervals are embedded within other, larger events or intervals, it is highly plausible that the embedded intervals come to be reanalysed without reference to their duration, that is, as discrete "points" within the greater interval; b) the second relates to the phenomenon of temporal compression: "past intervals held in memory may, due to the erosion of episodic memory, lose their durational significance, and accordingly become point-like" (Evans, 2004, p. 129).

What seems then to distinguish the moment sense from the duration one is the fact that the event or interval to which it refers has lost almost any durational significance, despite maintaining its own temporal uniqueness and specificity: the time at which something happens is not the same as another time. In terms of Mach's revised hypothesis, and in comparison with the attentional operations involved in the production of the durational sense, this can be obtained through limiting the acts of focusing A_t to the minimum number, that is one. One more condition has to be met, anyway, in order to produce the moment sense. Indeed, the moment sense also implies the reference to the continuum of temporal sequences: "the Moment sense relates to a purely temporal event, i.e., an event defined purely in terms of its relation to a temporal event-sequence" (Evans, 2004, p. 137). Therefore, the production of the moment sense requires that the act of focusing by A_t be placed inside the more general framework of the temporal continuum.

5. 2 The lexical item *moment*

In my opinion, a meaning similar to the moment sense of the lexical item *time* but that does not require the reference to the temporal continuum is one of the meanings associated with the lexical item *moment*. As one can see from the following examples, no reference is made to any temporal framework: "He thought for a moment before replying"; "She answered without a moment's hesitation"; "Could you wait a moment please?"; "One moment please"; "I will be back in a moment". In these cases, what is elicited is the experience of a very short interval considered by itself, without any reference to an external, preceding and following flow of events. Furthermore, the meaning associated with the lexical item *moment* seems to imply a certain amount of duration that the moment sense of the lexical item *time* does not possess. While the latter has certainly the quality of being "instant-like" or "point-like" ("What time is it?"), the former entails anyway a

certain temporal extent, consistency or "thickness" (to the point that it can be "long", as in: "There was a long moment of silence in the room as the sharp division between students and teachers soaked in") that the latter lacks. This characteristic is most probably produced by having A_t perform at least two acts of focusing.

5.3 The instance sense

A case similar to the meaning associated with the lexical item *moment* is that of the "instance sense" of the lexical item *time*. As evidenced by Evans (2004), the instance sense prompts for a reading in which an instance of a particular event, activity or process is being referenced: "Devine improved for the fourth time this winter when he reached 64.40 metres at a meeting in Melbourne"; "This time, it was a bit more serious because I got a registered letter". In terms of the concept elaboration criterion, it appears that the instance sense has no particular patterns of conceptual imagery associated with it. "This may follow as an instance is precisely that, an instance (of something else). Hence, instances only have structure in so far as they are tokens of other types of experiences, and have no inherent structure beyond the experiences they are instances of" (Evans, 2004, p. 134). In terms of the grammatical criterion, the instance sense is highly distinctive: it can be formalised, like the moment sense, as a count noun; however, unlike the moment sense (and the duration sense), the instance sense can be pre-modified by both ordinal numbers and cardinal numbers. This follows as the instance sense relates to distinct occurrences of the same event, and hence is iterative.

That the instance sense constitutes an additional meaning not apparent in the other sense is moreover evidenced by the fact that languages different from English use different lexical items to express the instance sense. Italian language, for example, uses the word *volta* ("This time, it was a bit more serious…:" = "Questa *volta* la faccenda è stata un po' più seria…").

The instance sense is then similar to the meaning associated with the lexical item *moment* in that both can be considered by themselves, without any reference to the backdrop of a temporal continuum constituted by an endless sequence of events, facts, etc. However, unlike the meaning associated with the lexical item *moment*, but like the moment sense of the lexical item *time*, the instance sense completely lacks any temporal consistency or "thickness".

5.4 The matrix sense

The various meanings associated with the lexical item *time* examined so far – the duration sense, the moment sense, the instance sense – have shown how it is possible to produce different meanings by progressively modifying and abstracting away from the same, original meaning. Without doubt, the extreme instance of abstraction, as far as the lexical item *time* is concerned, is represented by what Evans call the Matrix Sense, which is exemplified by sentences such as: "Time, of itself, and from its own nature, flows equably without relation to anything external"; "Time flows/runs/goes on forever"; "Time has no end"; "Nothing can outlast time"; "We live in time".

According to Evans' analysis, the matrix sense, unlike the other meanings associated with the lexical item *time*, indexes an unbounded entity which has an infinite elapse and is not constrained by the interval holding between individual events: an entity whose passage is unaffected by external events and within whose frame events unfold and states persist. As such, it is conceived as a manifold which contains and subsumes all other events and is thus independent of them. It is the objective time of physics and physicians, which radically differs from the subjective conscious experience of time.

The matrix sense seems then to differ from the other senses for the fact that it elicits the conscious experiences of something: a) infinite, unbounded; b) akin to a kind of backdrop against which other events occur; c) independent of any external events.

Let us examine how these conscious experiences can be produced. Generally speaking, it is quite realistic, as we have seen, to conceive of the time of physics as a construction developed on the subjective experience of time: indeed, what we come to know of the world is known primarily in and through our conscious experience. Therefore, the specific conscious experiences the matrix sense elicits can reasonably be thought to be derived from the more fundamental subjective experiences of time by means of some operations of abstraction.

In my opinion, in order to reach or produce the level of abstractness referred to by the matrix sense, human beings had to perform at least two fundamental steps. The first one was that of correlating or associating their subjective experience of duration with some *recurring, cyclical event*, whether it was natural, such as the daily rhythm of day and night, or artificial, such as the running of the sand out of the upper chamber into the bottom chamber of hourglasses. If, on the one hand, this first step allowed human beings to more precisely estimate durations, ridding themselves of the variability characteristic of the subjective sensation of time (a variability that is the direct cause of the phenomena of the experiences of protracted duration and temporal compression: see Flaherty, 1999), on the other hand, by implying the assignment of what is a subjective sensation to

an external event or object, it gave them indirectly the great opportunity to realize that even external event may possess, and be characterized by, their own, albeit limited, duration. Therefore, duration could also be envisaged as something objective, belonging to external events and objects, and independent of what human beings could subjectively experience. Moreover, human beings could begin to use specific external objects and events (such as hourglasses) to represent, measure and keep trace of specific durations.

The second step was represented by a process of further reification by means of which duration became completely independent of any event or object. Most probably, this process was occasioned by the observation that certain events (such as the daily hours of sunlight) either contain many other shorter events, or can be conceived as being formed by the juxtaposition or combination of many shorter events. Indeed, once this kind of observation was made, the possibility was open to imagine longer and longer durations or periods, so as to arrive at the extreme extent of conceiving an unbounded duration capable of containing all sorts of events and durations.

In terms of Mach's revised hypothesis, the conscious experience elicited by the matrix sense may be obtained by associating A_t with an entity a) that has the properties of being recurring or cyclical, or of being able to give rise to recurring or cyclical events; b) whose boundaries are not and cannot be defined or specified (this is precisely the characteristic of events or entities such as God or the Universe that are conceived of as subsuming all the other events and entities). In this way the amount of labour performed by A_t is freed from any subjective variability and left undefined.

It must be noticed that the achievement by human beings of the level of abstraction referred to by the matrix sense required, most probably, was a gradual conceptual and evolutional process implying a lot of time, and that it was not a sudden accomplishment. This hypothesis seems to receive support from the observation that human beings need some years to develop a consistent conceptual system able to represent and account for the abstract forms of time referred to by the matrix sense. As evidenced by studies of developmental psychology (Droit-Volet, 2001), until the age of 4 children can only live time, but they cannot think about it: that is, they can reproduce the durations of certain actions, compare the durations of different actions, etc. but they cannot yet represent time as an abstract entity, or as a reference framework. Only at 6 can they conceive time as something that can be measured, and it is only at 11-12 that they can conceive time as a completely arbitrary entity.

Let me make a final observation in connection with the matrix sense and the objective sense of time it entails. In this work, I have defined the conscious experience of time in terms of attentional operations, and, consequently, of the quantity of labour performed by the organ of attention, or, alternatively, the expenditure of the nervous energy supplied by the organ of attention for the

temporal task. It must be noticed, however, that when I state that phenomenal time derives from some form of energy, I do not mean at all that this kind of time is like, or can even be assimilated to, the Newtonian absolute time, which "flows equably without relation to anything external", that is, a kind of time existing in itself, independently of anything else, which only represents the true and real time, and against which any other kind of time has to be compared, or to which any other kind of time has to be referred. Neither do I mean that time is, more in general, something that "really" exists as an ontological entity, having its own life independent of us, and of our mental and perceptive activity, which is the only thing that gives it life. Neither, finally, do I mean that time is the cause or lies at the origin of the expenditure of the aforesaid form of energy. On the contrary, I think that: a) time is, like all other notions, concepts, meanings, ideas and representations, a product of human beings' mind and thought, that is, something human beings have mentally constructed; b) they have constructed it for their own adaptive and developmental purposes; c) in order to construct it, human beings have used as building blocks the expenditure of nervous energy associated with, and due to, the labour of attention. Therefore, when I say that time is a form of energy, I mean that it is a construction of human mind activity and that it could not exist without such an activity; a construction based primarily on the energy consumed in order to perform attentional activity. If we can speak of time as a form of energy, it is precisely because we have constructed it as such.

5.5 Concluding remarks

What can be considered the most elementary and primitive experiences of times, that is, duration and moment, served, in my opinion, as the basis on which some other, more elaborated, temporal constructs and notions were developed: succession, sequence, order, after, before, now, yesterday, tomorrow, when, past, future, present, day, month, year, to last, to continue, etc. This is primarily suggested by the fact that the duration sense of the lexical item "time" is characterized by the conscious experiences of one-dimensionality, irreversibility, and orderability, which evidently make the existence of constructs such as "succession", "sequence", "order", "after", and "before" possible. If we consider, for example, that a given event A can be associated with a certain level of expenditure of the nervous energy supplied by the organ of attention for the temporal task, an event B that is associated with a greater expenditure of attention appears to us to happen "after" A, whereas an event C that is associated with a lesser expenditure of attention appears to us to happen "before" A. This same fact, moreover, lets us understand how we can build a "succession" or "sequence" of events, actions, etc. out of the levels of nervous energy associated with them. Since

the level can only increase, this makes it possible for us to arrange or order events, actions, etc. in a univocal and exact way: precisely, in a temporal way.

The possibility of developing more elaborated temporal constructs – among which the more important one is represented, without doubt, by the grammatical category of verb - out of the elementary experiences of time is also suggested by the pioneering work by Ceccato and Zonta (1980) who gave a first indication of how one can derive some of these constructs from the more basic construct "time" (Italian, "tempo"). A similar proposal has also been recently put forward by Benedetti (forthcoming), even though within a new analytical framework.

The analysis of these constructs, however, requires a specifically dedicated work, which goes beyond the limited scope of the present paper.

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References

Angrilli, A., Cherubini, P., Pavese, A. and Manfredini, S. (1997). "The influence of affective factors on time perception". *Perception & psychophysics, 59 (6)*: 972-982.

Ariel, M. (2002). "The demise of a unique concept of literal meaning". *Journal of Pragmatics: 34*, 361-402.

Benedetti, G. (2001). *Semantica operativa. La semantica in termini di operazioni mentali. Parte prima. Principi generali, metodologia e tecnica di analisi*. www.mind-consciousness-language.com.

Benedetti, G. (forthcoming). *I meccanismi del pensiero e del linguaggio. Una barriera invalicabile?*

Benussi, V. (1913). *Psychologie der Zeitauffassung*. Winter, Heidelberg.

Block, R. A. (1979). "Time and Consciousness". In: Underwood, G. and Stevens, R. (1979) (eds.): *Aspects of consciousness. Vol. I. Psychological issues*. Academic Press. London.

Block, R. A. (1982). "Temporal judgments and contextual change". *Journal of Experimental Psychology: Learning, memory, and Cognition, 8*: 530-544.

Block, R. A. (1986). "Remembered duration: imagery processes and contextual encoding". *Acta Psychologica, 62*: 103-122.

Block, R. A. (1990). "Model of Psychological Time". In: Block, R. A. (1990) (ed.): *Cognitive models of psychological time*. Lawrence Erlbaum Ass. Hillsdale, New Jersey.

Block, R. A. (2003). "Psychological timing without a timer: The roles of attention and memory", In Helfrich, H. (2003) (ed.): *Time and Mind II: Information Processing Perspectives*. Hogrefe & Huber Publishers. Göttingen, Germany.

Block, R.A. and Reed, M.A. (1978). "Remembered duration: evidence for a contextual-change hypothesis". *Journal of Experimental Psychology: Human Learning and Memory, 4*: 656-665.

Block, R.A. and Zakay, D. (1996). "Models of psychological time revisited", In Helfrich, H. (1996) (ed.): *Time and Mind*. Hogrefe & Huber Publishers. Seattle, WA.

Block, R.A. and Zakay, D. (2001). "Retrospective and prospective timing: Memory, attention, and consciousness", In Hoerl, C. and McCormack, T. (2001) (eds.): *Time and memory. Issues in philosophy and psychology*. Oxford University Press. Oxford.

Bloom, P. (2000). *How Children Learn the Meanings of Words*. The MIT Press. Cambridge, Mass.

Bozzi, P. and Vicario G.B. (1960). "Due fattori di unificazione fra note musicali: la vicinanza temporale e la vicinanza tonale". *Rivista di psicologia, 54*: 235-258.

Brown, S. W. (1985). "Time perception and attention: The effects of prospective versus retrospective paradigms and task demands on perceived duration". *Perception & Psychophysics, 38*: 115-124.

Ceccato, S. (1969) (ed.). *Corso di linguistica operativa*. Longanesi. Milano.

Ceccato, S. (1972). *La mente vista da un cibernetico*. Eri. Torino.

Ceccato, S. and Zonta, B. (1980). *Linguaggio consapevolezza pensiero*. Feltrinelli. Milano.

Churchland, P. S. and Sejinowski, T. J. (1992). *The Computational Brain*. MIT. Cambridge, MA.

Coull, J. T., Vidal, F., Nazarian, B., and Macar, F. (2004). "Functional Anatomy of the Attentional Modulation of Time Estimation". *Science, 303*: 1506-1508.

Dennett, D. C. and Kinsbourne, M. (1992). "Time and the Observer: the Where and When of Consciousness in the Brain". *Behavioural and Brain Sciences, 15 (2)*: 183-247.

Droit-Volet, S. (2001). "Les différentes facettes du temps". *Enfances et Psy., 13*: 26-40.

Eagleman, D. M., Tse, P U., Buonomano, D., Janssen, P., Nobre, A. C., and Holcombe, A. O. (2005). "Time and the Brain: How Subjective Time Relates to Neural Time". *The Journal of Neuroscience, 25 (45)*: 10369-10371.

Evans, V. (2004). *The Structure of Time. Language, meaning and temporal cognition*. John Benjamins Publishing Company. Amsterdam/Philadelphia.

Fingelkurts, A. A. and Fingelkurts, A. A. (2006). "Timing in cognition and EEG brain dynamics: discreteness versus continuity". *Cognitive Processing, 7*: 135-162.

Flaherty, M. (1999). *A watched pot: How we experience time*. New York University Press. New York.

Fraisse, P. (1963). *The psychology of time*. Harper & Row. New York.

Franceschini, A. (1998). *Funzione di Stevens nella psicofisiche delle durate*. Tesi di laurea non pubblicata. Facoltà di Psicologia. Università di Padova.

Friedman, W. J. (1993). "Memory for the time of past events". *Psychological Bulletin, 113*: 44-66.

Friedman, W. J. (2001). "Memory Processes Underlying Humans' Chronological Sense of the Past". In: Hoerl C. and McCormack T. (2001) (Eds.): *Time and memory. Issue sin philosophy and psychology*. Clarendon Press. Oxford.

Friedman, W. J., and Wilkins, A. J., (1985). "Scale effects in memory for the time of events". *Memory & Cognition, 13*: 168-175.

Gibson, J. (1975). "Events are perceivable but time is not", In Fraser, J.T. & Lawrence, N. (eds.): *The study of time II*. Springer-Verlag. New York.
Gibson, J. (1986). *The ecological approach to visual perception*. Lawrence Erlbaum. Hillsdale, NJ.
Glasersfeld, E. von. (1985). "Reconstructing the concept of knowledge". *Archives de Psychologie, 53*:91-101.
Goodson, F. E. (2003). *The Evolution and Function of Cognition*. Lawrence Erlbaum. Mahwah, NJ.
Hicks, R.E., Miller, G.W. and Kinsbourne, M. (1976). "Prospective and retrospective judgments of time as a function of amount of information processed". *American Journal of Psychology,* 90: 431-446.
Hicks, R.E., Miller, G.W., Gaes, G. and Bierman, K. (1977). "Concurrent processing demands and the experience of time-in-passing." *American Journal of Psychology,* 89: 719-730.
Hoagland, H. (1933). "The physiological control of judgments of duration: evidence for a chemical clock". *Journal of General Psychology, 9*: 267-287.
Hoagland, H. (1935). "Pacemakers in relation to aspects of behavior". *Exper. Biol. Mono.* Macmillan.
Jackendoff, R. (1983). *Semantics and cognition*. MIT Press. Cambridge.
Jackendoff, R. (1992). *Languages of the mind*. MIT Press. Cambridge.
James, W. (1890). *The Principles of Psychology*. Holt. New York.
Kahneman, D. (1973). *Attention and effort.* Prentice Hall. Englewood Cliffs, NJ.
Kanabus, M., Szelag, E., Rojek, E. and Pöppel, E. (2002). "Temporal order judgement for auditory and visual stimuli". *Acta Neurobioogiae Experimentalis, 62*: 263-270.
Ladefoged, P. and Broadbent, D.E. (1960). "Perception of sequence in auditory events". *Quarterly Journal of Experimental Psychology, 13*: 325-349.
Lakoff, G. and Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to western thought*. Basic Books. New York.
Large, E, W. and Jones, M. R. (1999). "The Dynamics of Attending: How People Track Time-Varying Events". *Psychological Review, Vol. 106, N0. 1*: 119-159.
Lavie, N. (1995). "Perceptual load as a necessary condition for selective attention". *Journal of Experimental Psychology: Human Perception and Performance, 21*: 451-468.
LeDoux, J. E. (1995). "Emotion: Clues from the brain". *Annual review of Psychology, 46*: 209-235.
Macar, F., Grondin, S., and Casini, L. (1994). "Controlled attention sharing influences time estimation". *Memory & cognition, 22*: 673-686.
Mach, E. (1883). *Die Mechanik in ihrer Entwickelung historisch-kritisch dargestellt*. Brockhaus. Leipzig.
Mach, E. (1890). C*ontributions to the Analysis of the Sensations*. The Open Court Publishing Company. La Salle, Illinois).
Mack, A. and Rock, I. (1998). *Inattentional Blindness.* Bradford Book. MIT Press. Cambridge, MA.
Marchetti, G. (2001). "A Theory of Consciousness". www.mind-consciousness-language.com
Marchetti, G. (2003). "Foundations of Attentional Semantics". www.mind-consciousness-language.com
Marchetti, G. (2005). "The importance of non-attentional operations for Attentional Semantics". www.mind-consciousness-language.com
Marchetti, G. (2006) "A presentation of Attentional Semantics". *Cognitive Processing, 7*: 163-194.
Mauk, M. D. and Buonomano, D. V. (2004). "The Neural Basis of Temporal Processing". *Annu. Rev. Neurosci., 27*: 307-340.
Miller, G. A. (1956). "The magical number seven, plus or minus two: Some limits on our capacity for processing information". *Psychological Review, 63*: 81-97.
Nakayama, K. and Mackeben, M. (1989). "Sustained and transient components of focal visual attention". *Vision Research, 29*: 1631-1647.
Öhman, A. and Soares, J. J. F. (1994). " 'Unconscious anxiety': Phobic responses to masked stimuli". *Journal of Abnormal Psychology, 103*: 231-240.
Ornstein, R. E. (1969). *On the experience of time.* Penguin Books. Middlesex, England.
Pashler, H. E. (1998). *The psychology of attention*. Massachusetts Institute of technology. Cambridge, Ma.
Penton-Voak, I. S., Edwards, Percival, A., and Wearden, J. H. (1996). "Speeding up an internal clock in humans? Effects of click trains on subjective duration". *Journal of Experimental Psychology: Animal Behavior Processes, 22*: 307-320.
Pöppel, E. (2004). "Lost in time: a historical frame, elementary processing units and the 3-second window". *Acta Neurobiologiae Experimentalis, 64*: 295-301.
Richelle, M., Lejeune, H., Perikel, J.-J., and Fery, P., (1985). "From biotemporality to nootemporality: Toward an integrative and comparative view of time in behaviour". In: Michon J. A. and Jackson J. L. (1985) (Eds.): *Time, mind, and behaviour*. Springer-Verlag. Berlin.
Rubin, E. (1949). *Esperimenta psychologica*. Munskgaard. Copenhagen.
Ruggiu, L. (1998) (ed.). *Filosofia del tempo*. Bruno Mondadori. Milano.
Shore, D. I., Spence, C. and Klein, R. M. (2001). " Visual prior entry". *Psychological Science, 12*: 205-212.
Shore, D. I. and Spence, C. (2004). "Prior Entry", In: Itti L., Rees G. and Tsotsos J. (2004) (eds.): *Neurobiology of attention*. Elsevier. North Holland.
Stern, L.W. (1897). "Psychische Präsenzzeit". *Zeitschrift für Psychologie und Physiologie der Sinnesorgane, 22*: 13-22.

Talmy, L. (2000). *Toward a Cognitive Semantics. Volume I: Concept Structuring System.* The MIT Press. Cambridge, Mass.

Thomas, E.A.C. and Brown, T.I. Jr. (1974). "Time perception and the filled-duration illusion". *Perception & Psychophysics, 16*: 449-458.

Thomas, E.A.C. and Weaver, W.B. (1975). "Cognitive processing and time perception". *Perception & Psychophysics, 17*: 363-367.

Trasforini, L. (1996). *Dislocazione temporale: tempi di reazione e resoconti soggettivi*. Tesi di laurea non pubblicata. Facoltà di Psicologia. Università di Padova.

Treisman, M. (1963). "Temporal discrimination and the indifference interval: Implications for a model of the 'internal clock' ". *Psychological Monographs, 77* (whole no. 576).

Treisman, M. (1984). "Temporal rhythms and cerebral rhythms". In: Gibbon, J. & Allen, L. (1984) (Eds.): *Timing and time perception*. New York Academy of Sciences. New York.

Tse, P. U., Intriligator, J., Rivest, J., and Cavanagh, P. (2004). "Attention and the subjective expansion of time". *Perception & Psychophysics, 66 (7)*: 1171-1189.

Varela, F. J., Toro, A., John, E. R., Schwartz, E. L. (1981). "Perceptual framing and cortical alpha rhythm". *Neuropsychologia, 19*: 675-686.

Vicario, G. B. (1963). "La 'dislocazione temporale' nella percezione di successioni di stimoli discreti. *Rivista di Psicologia, 57*: 17-87.

Vicario, G. B. (1965). "Vicinanza spaziale e vicinanza temporale nella segregazione degli eventi. *Rivista di Psicologia, 59*: 843-863.

Vicario, G. B. (2005). *Il tempo. Saggio di psicologia sperimentale*. Il Mulino. Bologna.

Ward, L. M. (2003). "Synchronous neural oscillations and cognitive processes". *Trends in Cognitive Science, Vol. 7, No. 12*: 553-559.

Wearden, J. H. (2001). "Internal Clocks and the Representation of Time". In: Hoerl, C. and McCormack, T. (2001) (Eds.): *Time and memory. Issue sin philosophy and psychology*. Clarendon Press. Oxford.

Wearden, J. H., Edwards, H., Fakhri, M., and Percival, A. (1998). "Why 'sounds are judged longer than lights': application of a model of the internal clock in humans". *Quarterly Journal of Experimental Psychology, 51B*: 97-120.

Wiener, N. (1948). *Cybernetics, or Control and Communication in the Animal and the Machine*. Wiley & Sons. New York.

Wierzbicka, A. (1996). *Semantics. Primes and Universals.* Oxford University Press. Oxford.

Wright, K. (2006). "Times of our lives". *Scientific American, Vol. 16, No. 1*: 26-33.

Wundt, W. (1902). *Grundzüge der physiologischen Psychologie.* Engelmann. Leipzig.

Wyss, R., König, P, and Verschure, P. F. M. J. (2002). "Invariant Encoding of Spatial Stimulus Topology in the Temporal Domain". *Neurocomputing, Vol. 44-46*: 703-708.

Wyss, R., König, P, and Verschure, P. F. M. J. (2003). "Invariant representations of visual patterns in a temporal population code". *Proceedings of the National Academy of Sciences of the United States of America, Vol 100, No. 1*: 324-329.

Zakay, D. (1998). "Attention allocation policy influences prospective timing". *Psychonomic Bulletin & Review, 5*: 114-118.

Zakay, D. and Block, R. A. (1997). "Temporal cognition". *Current Directions in Psychological Science, Vol. 6, No. 1*: 12-16.

Zakay, D., and Block, R. A. (2004). "Prospective and retrospective duration judgments: an executive-control perspective". *Acta Neurobiologiae Experimentalis, 64*: 319-328.

Zakay, D. and Tsal, Y. (1989). "Awareness of attention allocation and time estimation accuracy". *Bulletin of the Psychonomic Society, 27*: 209-210.