Commentary on Giovanni Bruno Vicario's

Il tempo. Saggio di psicologia sperimentale

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One of Vicario's main concerns in this work[1], and most probably his most important one, is showing that phenomenal time, that is, "what appears to us in consciousness: perceptions, memories, emotions, and thoughts *as they appear to us*" (Vicario, 2005, p. 13)[2], is not the same as, and cannot be reduced to, the time of physics, or physical time: "the concept of time in physics has nothing to do with the time of experience any longer" (Vicario, 2005, p. 34)[3]; "it is not reasonable to want to reduce phenomenal time to physical time, or to the physical time of physiological processes" (Vicario, 2005, p. 122)[4]. This concern is based on the observations that:

a) Notwithstanding the various *distinguos* put forward by many influential psychologists as regards the investigation of time and its related topics[5], there is still a widespread belief among psychologists: i) that phenomenal time should be considered in the same way as physical time, that is, as possessing the same characteristics and qualities of the time of physics (Vicario, 2005, p. 102)[6] , and ii) that the former should be analyzed in terms of the latter;
b) Despite the admonitions of scientists like Ernst Mach (1883), many psychologists still believe in the existence of the Newtonian "absolute" time of physics. The belief in the existence of the

[1] This book is the first volume of a two-volume set. The index of the not yet published second volume comprises the following chapters: Flow; Change; Present; *Kairós;* Time and Reality; Time and Causation; Time and Rhythm; Time and Ageing; Time in Mental Illness; Time and Drugs; Pictorial Representation of Time; Development of the Notion of Time; Fraser's Table; Epilogue.
[2] "L'aggettivo *fenomenico* (…) indica ciò che appare a livello della coscienza: percezioni, ricordi, emozioni e pensieri per *come ci appaiono*" (Vicario, 2005, p. 13).
[3] "La mia impressione è che il concetto di tempo in fisica non abbia ormai nulla a che fare con il tempo dell'esperienza" (Vicario, 2005, p. 34).
[4] "Credo che non sia ragionevole voler ridurre il tempo fenomenico al tempo fisico, o al tempo fisico dei processi fisiologici" (Vicario, 2005, p. 122).
[5] See for example what Fraisse says about the perception of simultaneity: "Since the advent of experimental psychology, it has been established that perceived simultaneity does not conform to physical simultaneity" (Fraisse, 1984, p. 4).
[6] "Gli psicologi – in generale – non si rendono conto che le caratteristiche del tempo fisico non possono essere estese al tempo fenomenico" (Vicario, 2005, p. 102).

> absolute time of physics leads psychologists to think: i) that this absolute time of physics is "realer" than the phenomenal one, and ii) that phenomenal time is a distortion of the time of physics: "The common practice is that of regarding the *entia rationis* of physics as real, and the discrepancies between the concepts of physics and actual experiences as *imperfections of the senses*, or as *illusions*" (Vicario, 2005, p. 96)[7].

According to Vicario, the hypotheses, or better the prejudices 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, cannot account for some important findings revealed by psychological experiments on the perception of simultaneousness, succession, and instantaneity, and on time estimation.

No doubt, one of the most striking and counter-intuitive phenomena described by Vicario concerns *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) 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

[7] "La pratica quotidiana è quella di considerare reali gli *entia rationis* della fisica e di considerare le discrepanze tra i

1760 and 1568 Hz respectively, and *b* is a low tone very different from the other two: 82,4 Hz (see Fig. 1a, adapted from Vicario, 2005, p. 112). For tones each lasting 100msec, subjects perceive a succession of high notes followed by a low note (see Fig. 1b). 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 (Vicario, 2005, p. 112)[8].

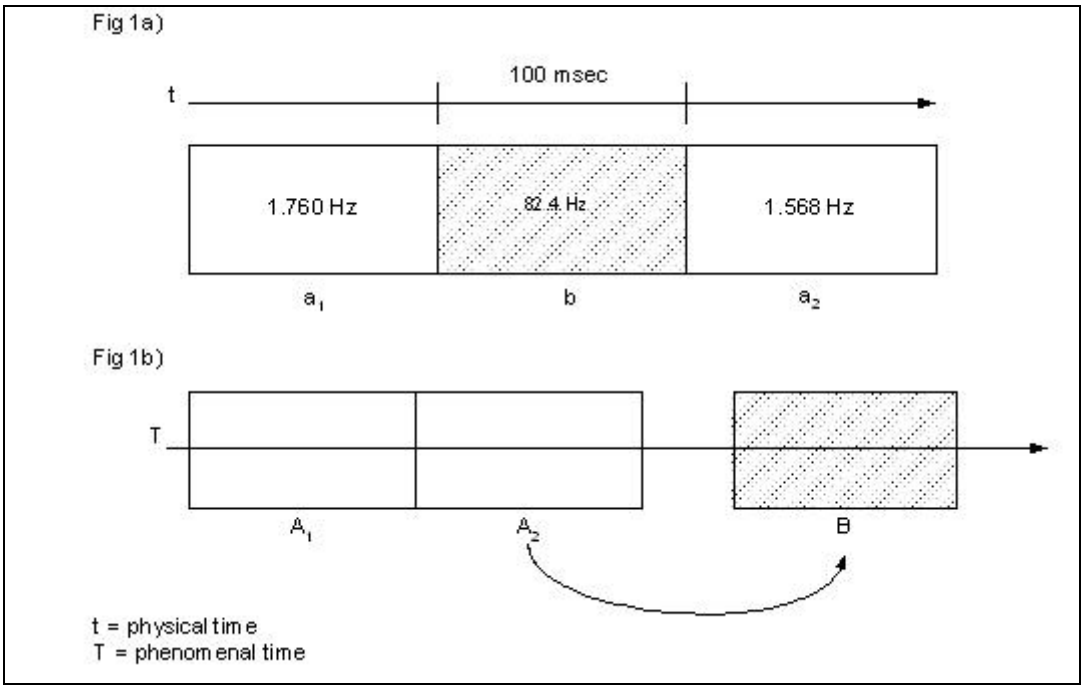

Fig. 1 (adapted from Vicario, 2005)

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 than150msec, 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

concetti della fisica e le esperienze concrete come *imperfezioni dei sensi* o *illusioni*" (Vicario, 2005, p. 96).

[8] "Tutto accade come se la successione di note simili per altezza avesse 'espulso' la nota dissimile, relegandola in un punto dove non può disturbare la successione" (Vicario, 2005, p. 112).

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.2a (adapted from Vicario, 2005, p.129) that repeats cyclically, they will hear a single sequence of low and high sounds if each stimulus lasts about 200msec (Fig. 2b), and *two different synchronized sequences* of sounds (a low trill and a high one) if each stimulus lasts about 50msec (Fig. 2c).

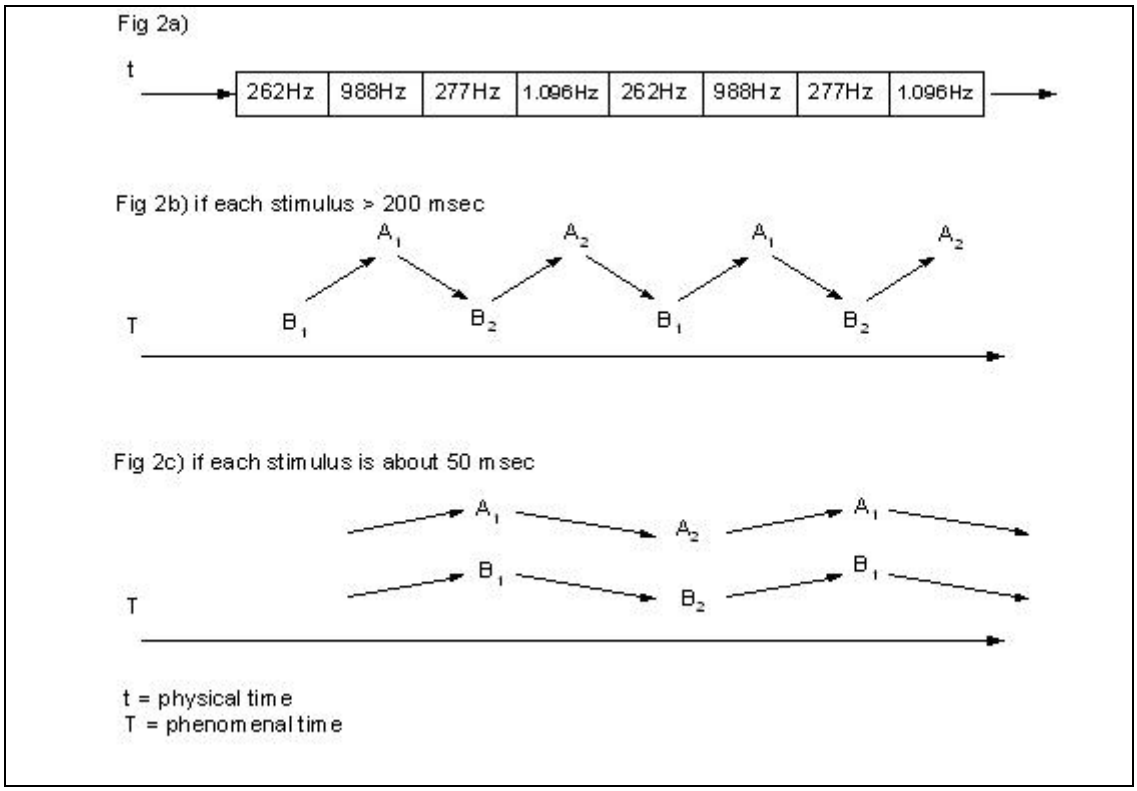

Fig. 2 (adapted from Vicario, 2005)

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: "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" (Vicario, 2005, p. 130)[9].

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[10].

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

[9] "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).

[10] "Tra la simultaneità percepita e la successione percepita trovano luogo impressioni varie, come di eterogeneità, di discontinuità, di movimenti apparenti *et similia*" (Vicario, 2005, p. 116).

continuous: As the phenomena described by Vicario show – the "tunnel effect" (Vicario, 2005, pp. 52-55), the "Renard effect" (Vicario, 2005, pp. 55-57), the perception of stopping (Vicario, 2005, pp. 57-59), the "window effect" (Vicario, 2005, pp. 59-62), the stroboscopic movement (Vicario, 2005, pp. 185-193) -, 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 (Vicario, 2005, pp. 185-217). As Vicario 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[11];
b) Cause and effect. As the "window effect" shows (Vicario, 2005, pp. 59-62), as well as the "phi phenomenon" (Vicario, 2005, pp. 185-187), 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: moreover, in perception, you can have causes without effects and effects without causes.

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 evidences revealed by experiments on perception, but also the obvious danger that they put forward or look for wrong motivations for these same evidences, thus prejudicing their research.

[11] "Certi attributi degli eventi percepiti, come spazio, tempo e velocità, non sono legati dalle stesse relazioni esistenti tra i corrispondenti attributi degli accadimenti fisici" (Vicario, 2005, p. 215).

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 (Vicario, 2005, p. 172-173).

According to Vicario, this really makes an absurd demand of subjects: "You expect that subjects estimate something, but you forbid them from using any way of measuring it"! (Vicario, 2005, p. 173)[12]. 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 events.

Equally senseless is, according to Vicario, the hypothesis put forward by many psychologists that identifies the basic mechanism that allows human beings to convert physical time into phenomenal time with an internal clock. According to this hypothesis, human beings are able to estimate durations of events because they are equipped with an internal clock that counts the cyclical processes occurring in their body or brain[13]. Now, as Vicario observes (Vicario, 2005, p. 165), it is certainly reasonable to believe in the existence of such counters or timers: indeed, only by means of them, can an organism correctly coordinate the phases of its movements. However, it is not reasonable to believe that it is a counter or a timer that evaluates time and duration. A counter or

[12] "Si pretende che il soggetto misuri qualcosa, e gli si vieta l'uso di un'unità di misura" (Vicario, 2005, p. 173).

a timer, like any clock, can only provide the raw material necessary for counting: but there must be someone who performs the counting: "The clock says the hour only when we look at it" (Vicario, 2005, p. 165)[14]. It is we who assign the physical mechanism - whether it is a pendulum, the sun, a clock, or something else - the capacity to estimate the duration. The senselessness of the hypothesis of the internal clock is further and ironically highlighted by the consideration 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!

Here Vicario points out an instance of a more general tendency, that is, explaining time by using time, or anyway concepts or notions related to time, or comprising time as their constituent, such as "duration", "period", "after", "before", "cycle", "rhythm", "sequence", "succession", "clock", "to last", "to become", etc. As I showed elsewhere (Marchetti, 2005), this is a common mistake made by many authors: for example, Aristotle saw time as the becoming, Saint Augustine as the present, Hume and Berkley as a succession of perceptions or ideas, Leibniz as order, Descartes as duration. In so doing, whoever wants to explain time by using a notion or concept that presupposes or contains time as its constituent, introduces an unavoidably endless circularity, where the *definiens* includes the *definiendum*, which it is not possible to get out of.

I think that Vicario's highlighting the difference between phenomenal time and physical time, and criticism of the attitude of those who disregard this important difference are not only correct but also opportune. Indeed, despite the fact that evidence of the difference between phenomenal time and physical time is too striking and convincing to be overlooked, many researchers still do not seem to be aware of the difference and of the dangers implied by disregarding it.

Equally convincing is his criticism of the hypothesis that phenomenal time is a kind of internal, subjective copy or representation of an external, objective, more basic, and truer form of time: the absolute time of physics. It is certainly more reasonable to think that the notion of the time of physics is a construction based and developed on the subjective, direct, phenomenal and more fundamental experience we have of time (Vicario, 2005, p. 13 and p. 35)[15]. After all, everything we know is known primarily in and through our conscious experience[16]. 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: "The vocabulary of physics

[13] For a review, see Wearden (2001).
[14] "*L'orologio dice l'ora soltanto quando noi lo guardiamo*" (Vicario, 2005, p. 165).
[15] "In linea di principio, non si può spiegare il tempo vissuto con il tempo della fisica, perché la nozione di tempo in fisica E costruita sulla considerazione di fatti osservabili che, bene o male, esistono soltanto nell'esperienza diretta" (Vicario, 2005, p. 35).
[16] As Vicario observes: "Direct experience is the origin and root of any knowledge" ("Principio e radice di ogni sapere è l'esperienza diretta", Vicario, 2005, p. 9).

derives from everyday language, which describes direct experience, that is, psychological experience" (Vicario, 2005, p. 13)[17].

What does not convince me of Vicario's thought are the consequences he seems to deduce from the observation that the absolute time of physics derives from phenomenal time. On the grounds of the primacy of phenomenal time, he states that "absolute time is neither a form of energy nor a form of information, but an abstract schema of relationships between events" (Vicario, 2005, p. 30)[18]. From here, he deduces that "it is not possible to carry out a psychophysics of time" (Vicario, 2005, p. 30)[19], because "psychophysics relates stimuli to responses, that is, forms of energy or information to behaviours, sensations, representations, emotions, etc." (Vicario, 2005, p. 30)[20].

In my opinion, here Vicario makes a mistake. I do not see a direct relation between the statement that "absolute time is not a form of energy" and the statement that "it is not possible to carry out a psychophysics of time". The fact that "absolute time is not a form of energy" does not necessarily imply that there cannot be a psychophysics of time. Indeed, some other kind of time, such as "*phenomenal* time", can be a form of energy, or derive from some form of energy, and, if it is, then there can be a psychophysics of time.

By stating that phenomenal time can be a form of energy, or derive 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, more in general, is something that "really" exists as an ontological entity, having its own life independent of us, of our mental and perceptive activity that 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 activity; a construction

[17] "I termini che si usano in fisica sono quelli che si sono sempre usati nel linguaggio quotidiano, che descrive l'esperienza diretta, quella psicologica" (Vicario, 2005, p. 13).
[18] "Il tempo assoluto non è una forma di energia o di informazione, ma uno schema astratto i relazioni tra eventi" (Vicario, 2005, p. 30).
[19] "*Non si può fare una 'psicofisica del tempo'* " (Vicario, 2005, p. 30).
[20] "La psicofisica mette in relazione stimoli e risposte, cioè forme di energia o di informazione con comportamenti, sensazioni, rappresentazioni, emozioni, ecc. " (Vicario, 2005, p. 30).

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.

The idea that phenomenal time is connected with, or derives from, some kind of consumption of energy, and precisely the organic consumption of the organ of consciousness or attention, was originally proposed by Ernst Mach (1886): "Since, so long as we are conscious, time-sensation is always present, it is probable that it is connected with the organic *consumption* necessarily associated with consciousness, - that 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 – where 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. 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 appear *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).

Current research on time perception, above all research adopting the prospective paradigm (Bloch and Zakay, 2001, Brown, 1985, Hicks et al., 1976, Thomas and Weaver, 1975), seems to strongly support a slightly modified version of Mach's hypothesis. 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. 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 time or "the experience of time-in-passing" would be not so much the total expenditure or labour of attention in general (as instead Mach's hypothesis seems to imply), nor the specific expenditure or labour of attention necessary to perform a certain activity or perceive a certain event, as the expenditure or 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 estimate the duration of a given event or interval, the longer the event or interval seems to last.

In my opinion, this can only mean that time-sensation is made possible by the following facts: a) we allocate a certain portion of our attention to this task (let us call it A_t); b) this allocated portion of attention (A_t) is associated with the portion of attention (let us call it A_e) required to perform the event or activity whose duration we have to estimate (to this regard, Vicario correctly observes: "Time does not exist in nature: only observable events do exist"[21]); c) 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 separate and independent streams of attention; d) the labour of A_t, A_t being associated with A_e, increases continually and proportionally with the expenditure of A_e; e) it is this 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 (or alternatively, of allocated attention expended) *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.

The hypothesis – which we can name "Mach revised hypothesis" - I have put forward here on how we human beings can have time-sensations and estimate duration, despite not being yet fully ascertained, seems capable nonetheless of opening up a new promising perspective on the study of phenomenal time.

Firstly, it gives a clear indication of the way in which to deal with the problem of the irreversibility of phenomenal time, that is, the fact that from a phenomenological point of view, time can only be experienced as irreversible: a problem which Vicario openly recognizes as a matter of fact ("We cannot experience time in a different way from that in which it actually occurs"[22]), but which he does not seem to be able to tackle. "Mach revised hypothesis", on the contrary, linking time-sensation with the organic consumption associated with the work of attention, or alternatively with the increase of the labour of attention, supplies an independent basis (the organic consumption, or the increase of labour of attention) on which to explain the unstoppable and irreversible flow of time.

Secondly, it accounts for the ability of human beings to *directly* perceive and estimate the duration of events, without resorting to the contradictory and circular hypothesis of internal clocks. Neither would it be necessary, in order to account for this ability, to put forward the not-always applicable hypothesis that human beings estimate time by resorting to some kind of counting strategy, as Vicario instead seems to propose at pp. 172-179. Actually, while it is certainly true that this strategy is used by human beings in many situations, nonetheless it is not always used, nor can it always be used: indeed, we are also able to estimate very long durations (of hours, days, or even months), in the sense of being able to feel that a lot of time has passed by, even if we have not and

[21] "Il tempo, come fatto di natura, non esiste. Esistono gli eventi osservabili" (Vicario, 2005, p. 9).

really cannot (who could keep counting for hours?) resort to any kind of explicit counting. After all, one of the most important abilities we human beings have is that of being able to feel our tiredness, weakness, fatigue, freshness, strength, force, etc., both physical and mental. Therefore, if we have this ability, why could we not use it to estimate what we call "duration"? Indeed, it is sufficient that we allocate part of our attention (what we called A_t) to the purpose, associate it with the attention (what we called A_e) required to perform the event we have to estimate, and perceive the amount of labour performed by A_t while the event takes place.

Just as happened for the problem of the irreversibility of phenomenal time, also regarding the ability of human beings to *directly* perceive and estimate duration of events, Vicario, despite acknowledging it (Vicario, 2005, p. 178 and p. 183), openly admits his incapacity to account for it: "How can the subject, let alone estimate, but even have, the sensation of *his* own duration? The question is so embarrassing as to make one wonder about its sensibleness" (Vicario, 2005, p. 183)[23].

Thirdly, "Mach revised hypothesis" provides, as we have seen, an explanatory basis for all those phenomena concerning the subjective expansion or contraction of time, whether evidenced by the research carried out in the prospective paradigm (Bloch and Zakay, 2001, Brown, 1985, Hicks et al., 1976, Thomas and Weaver, 1975), which shows how the degree of attention directed to the flow of time itself greatly affects the experience of duration, or by the research on the perception of dangerous or strange events (Tse et al., 2004), which shows how the degree of attention directed to the perception of odd events greatly contributes to the subjective expansion of time.

Fourthly, it accounts for the way we estimate the duration of past events, or remembered duration: a phenomenon that is investigated under the retrospective paradigm (Block and Zakay, 1997, 2001, Brown, 1985, Hicks et al., 1976, Ornstein, 1969, Zakay and Block, 2004). Generally speaking, there seems to be an inverse relation between the way we estimate the duration of past events (retrospective paradigm) and the duration of events that have not yet taken place (prospective paradigm)[24]. As William James observed, "In general, a time filled with varied and interesting experiences seems short in passing, but long as we look back. On the other hand, a tract of time empty of experiences seems long in passing, but in retrospect short" (James, 1983, p. 587). According to Block and Zakay (Zakay and Block, 2004), who experimentally ascertained under what conditions the inverse relation described by James takes place, the difference between the way we experience and estimate duration in the retrospective condition and in the prospective one is due to two different underlying cognitive processes: "In the retrospective paradigm, remembered duration lengthens proportionally to the number of changes in cognitive context that were encoded

[22] "A noi non è dato di esperirlo (il tempo) in maniera differente da quella che di fatto si verifica" (Vicario, 2005, p. 72).
[23] "Come fa il soggetto, non dico a valutare, ma semplicemente ad avere la sensazione della *propria* durata? La domanda è a tal punto imbarazzante da far nascere il sospetto che sia priva di senso" (Vicario, 2005, p. 183).

during the time period and are able to be retrieved after it ends. (…) In the prospective paradigm, experienced duration lengthens proportionally to the amount of attention that a person allocates to processing temporal information" (Zakay and Block, 2004, p. 326). Remembered duration (that is, the duration experienced under the retrospective paradigm) would thus rely mainly on (information retrieved from) memory, and experienced duration (that is, the duration experienced under the prospective paradigm) would rely more on attention (to time).

Contrary to Block' and Zakay's opinion, 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, that is, attention to time. From both an evolutionist point of view and a pragmatic one, it would really be uneconomic and unreliable for us to rely on two different processes to estimate the same thing (time). Obviously, 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, and consciously experiencing it again. Therefore, when estimating past events, it is as if we live them again, even if for a short period. 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 the other cases we estimate the duration of a past event by allocating part of our attention to this purpose, associating it with the retrieved information and perceiving the amount of labour it has performed while the event is consciously remembered. Obviously, 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. Anyway, the important aspect about the retrospective condition, as has been evidenced by Block and Zakay's work, is that not all kinds of information are equally useful for the purpose of estimating the duration of a past interval: in fact, we specifically rely more on the contextual changes that occurred during the interval, than, for example, on stimulus complexity (most probably because contextual changes allow us to better reconstruct what happened during the interval).

Attention also explains the inverse relation, described by James and ascertained by Block and Zakay, between the way we estimate the duration of past events and the duration of events that have not yet taken place (prospective paradigm). The prospective paradigm used by Block and Zakay involves a concurrent situation that distracts attention from time estimation, whereas the retrospective paradigm does not involve it: it only requires that subjects pay full attention to the

[24] But not always: see for example Brown (1985).

estimation of duration. In this view, the retrospective condition can be assimilated to the prospective condition in which subjects are not required to divide their attention between a temporal information task and a non-temporal information task, but simply have to allocate their full attention to the estimation of duration. As psychological experiments show, in cases of prospective duration judgements when no concurrent processing of stimuli is required of subjects, the ratio of judged duration to real duration increases as a function, for example, of the oddness or improbability of the stimuli (Tse et al., 2004). Subjects behave then in the retrospective condition in the same way as they do in those prospective conditions that do not require the performance of a secondary, non-temporal information task: being required to pay full attention only to the event whose duration they are required to estimate, they experience an expansion of time that is directly proportional to the information retrieved from memory.

Fifthly, "Mach revised hypothesis" accounts for the human ability to perceive the succession or order of events, that is, the fact that an event comes "before", "after" or "at the same time as" another: an ability that is also at the basis of the notion of "past", "present" and "future". As Mach observed, "the sensations connected with greater expenditure of attention appear to us to appear *later*" (Mach, 1890, p. 112): that is, using the terms of the "Mach revised hypothesis", the event associated with the highest degree of labour of the portion of attention allocated to the perception of time (A_t) is the one coming "later" or "after"; conversely, the event associated with the lowest degree of labour of the allocated portion of attention is the one coming "first" or "before".

The importance of attention for the perception and mental construction of order and succession is partly evidenced by the phenomenon of "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. 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).

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. In my opinion, 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 an indication of the facts that: attention is a cyclical phenomenon; each attentional cycle has a certain minimal duration; and attentional cycles represent the building blocks of conscious experience[25]. 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.

[25] On this point, see also Pöppel (2004).

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