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# An interdisciplinary study of time in language and mind

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Abstract

How does the mind come to have a concept of time? This dissertation explores a potential solution to this age-old problem: our representation of time (and our reasoning about it) is based on our knowledge and representation of space. The theory explored here suggests that, like other abstract conceptual domains, time is represented by 'recycling' conceptual structure that derives from physical interactions with the world, such as the concrete conceptual domain of spatial relations. Therefore, our representation of time is metaphorical: We think about time in terms of space. This metaphorical conceptual relationship is reflected in language, where we often use spatial metaphors to talk about time (e.g., a *long* vacation; a *short* meeting).

I have explored the proposal that time is mentally represented in terms of space through: i) a philosophical review and epistemological analysis of the concept of time and its spatialization; ii) psychophysical and psycholingustic experimentation on the relationship of space and time in our mind, and its cultural variability; iii) Linguistic field work I conducted in the Brazilian Rainforest in an indigenous Amazonian population.

In the first part of this dissertation, I show that: a) the concept of time has been progressively *spatialized* through the course of occidental philosophy and science, from Plato to Newton and Kant, so that it can be measured and understood as an object of experience; b) in psychological science, time has been treated as a natural kind, and temporal experience has been investigated as a sensory process, like vision or touch; c) the experience of time can be better understood as an abstract conceptual domain (rather than as a *sense*), which is independent of an external physical time (if this exists). Following this analysis, the theory according to which time is represented in terms of space, through metaphorical construction (Metaphor Theory), is described in detail.

In the second part, I begin by reviewing psychological studies showing that spatial conceptual structures are activated during temporal reasoning. The majority of these studies are equally supportive of two theories: ATOM (A Theory Of Magnitude; Walsh, 2003) and Metaphor Theory (Lakoff & Johnson, 1999). Metaphor Theory predicts that space and time are asymmetrically related in the human mind, as they are in language (where we use space to talk about time more than vice-versa). ATOM also

predicts that space and time are strictly coupled in mind, but that they are symmetrically related. To distinguish these theories, I conducted a pair of psychophysical experiments, the results of which strongly suggests that, in the human mind, time depends on space more than vice-versa. This asymmetrical relationship supports Metaphor Theory and challenges ATOM.

The third part of this dissertation approaches the issue of the cultural and linguistic relativity of our concept of time. First, I provide experimental evidence that orthography plays a causal role in shaping the way time is conceptualized along a lateral spatial axis, resulting in different implicit mental representations of time across cultures. Next, I discuss to what extent the languages we speak can shape the way we think about time, and whether reliance on some sort of spatial mapping to conceptualize time is a human universal (despite cross-cultural and cross-linguistic variation). I provide an analysis of this question on the basis of previous studies of linguistic relativity, and on preliminary linguistic data I collected from an indigenous Brazilian Amazonian population, the Amondawa.

In the final part, I syntheisize the conclusions of these philosophical, psychological, and linguistic investigations, and offer a critical analysis of the proposal formulated by Lakoff & Johnson (1999) regarding the universality of spatial conceptual metaphors for time.

## Contents

# Introduction

> A human being should be able to change a diaper, plan an invasion, butcher a hog, conn a ship, design a building, write a sonnet, balance accounts, build a wall, set a bone, comfort the dying, take orders, give orders, cooperate, act alone, solve equations, analyze a new problem, pitch manure, program a computer, cook a tasty meal, fight efficiently, die gallantly. Specialization is for insects.
>
> *Robert A. Heinlein*

There are many questions in science which require an interdisciplinary view. Understanding how the human mind can grasp the concept of time is probably one of those. It doesn't really matter from which point you start. The deeper you go in your investigation, the more the mesh of the conceptual sieve your discipline has provided you becomes too large to grasp the precious stone you are looking for.

But you can always superimpose your former sieve on a new one. Then the psychologist wants to talk with a linguist, the linguist starts looking for an anthropologist, the anthropologist might brush off his old philosophy books, the philosopher starts to write cryptic e-mails to his physicist friends, and the physicist might come back to see the psychologist, probably for different reasons. For the close friends that might read this introduction and worry about my mental health, I want to comfort them by saying that I've understood long ago that I cannot be a psycho-anthro-linguo-philo-cist, or whatever. In the context of Heinlein's quotation, I definitely look more like an insect than a human being.

Nevertheless, from the somewhat stable ground of psychology, I tried to learn from readings in philosophy, neuroscience, linguistics and anthropology: fields of knowledge that ultimately are part of the discipline called "cognitive science," which is interdisciplinary by definition. I've read a lot; I've understood what I could. The result is this thesis, which is more serious (for better or for worse) than this short introduction.

To those who undertake to read this thesis, I would suggest beginning from the end. Chapter 13, the "General conclusions," is a sort of travel diary where I tried to retrace the *fil rouge* of this long coverage without overstaying on particulars, and highlighting the principal achievements. This may provide the reader with a better idea of which parts will be of interest than simply looking at the table of contents.

# PART 1
# The concept of time

# 1. The beginning of time

In western culture, *time* is the dimension in which we conceive and measure the passing of events. Each event in time can be in the past, the present or the future.

Although quite obvious to our educated 'eye,' it might be possible that such an abstract concept of time is as much a cultural invention as Zeus or American Idol. This is quite a bizarre claim for a mind used to thinking about time as a natural kind like water or wind, and to relying on a temporal sense (maybe like the Kantian *inner* sense) comparable to the sense of sight or hearing. In this work, I will try to demonstrate that time is neither a natural kind nor an 'inner sense' or an *a-priori* condition for human experience and knowledge. As Albert Einstein pointed out: "Space and time are modes by which we think, not conditions under which we live."

There are few better ways to relativize what seems to be an absolute truth than to put it into historical context. In the Iliad, there is not a term equivalent to our "time," to designate an abstract and continuous flux, and there is not a word for 'eternity'.[1] The term *aiòn*, which in Plato has the meaning of eternity, for the early Greeks was the time of the life, the *élan vital*, the vital flux (Gianetto, 2005; Von Franz, 1992). Losing the *aiòn* was losing the life:

> τοὔνεκά μιν κάλεον Σιμοείσιον· οὐδὲ τοκεῦσι
> θρέπτρα φίλοις ἀπέδωκε, μινυνθάδιος δέ οἱ αἰὼν
> ἔπλεθ' ὑπ' Αἴαντος μεγαθύμου δουρὶ δαμέντι.

That's why the people called him Simoeisius. But he did not repay his fond parents for raising him. His life was cut short on great Ajax's deadly spear. Homer, *Iliad* , IV (477 - 479)

[1] There is a word for immortality: the gods are born (as are humans) but they don't die. They never lose the *aiòn*.

τὸν δ' ἄρ' ἐπ' ἀκτῆς εὗρε καθήμενον· οὐδέ ποτ' ὄσσε δακρυόφιν τέρσοντο, κατείβετο δὲ γλυκὺς αἰὼν νόστον ὀδυρομένῳ, ἐπεὶ οὐκέτι ἥνδανε νύμφη.

She found him by the shore, sitting down there, with his eyes always full of tears, because his sweet life was passing while he mourned for his return. The nymph no longer gave him joy. Homer, *Odyssey* , V (151 - 153)

As explained by Marie Von Franz (1992), in most of the ancient conceptualizations of time the distinction between past, present and future did not have a definite reality. Time, in its more concrete sense of 'vital juice' that pervades any living being, is conceived of as a deity or one of its manifestations. This is the time of myth. Also in ancient India, writes Von Franz, we can find this archetypal symbolization of time as a deity and as the flux of life and death. In the Bhagavadgita (IV-III Sec. a.C.) Krishna says of himself: "I'm the time which destroy all the world, appeared to take all the men" (Von Franz, 1992). Among the Maya and Aztec, we find the same relationship between time and the creative cosmic energy that originates from God. The most frequent Mayan word to design time, *kin*, is represented by the hieroglyph which means 'sun' or 'daylight,' and the Aztec associated time with a god, Omoteotl, father and mother of everything, "god of fire" and "god of time" (Von Franz, 1992). In China, time was not depicted as an abstract parameter, an empty matrix. Rather, the word "time", *che*, meant a moment that could be seized for performing an action.

The lack of a neat distinction between the past and the future to which Von Franz refers is related to a cyclical, circular representation of time in which the future perpetuates the past and all the events will return. There is a 'before,' then 'after,' then again 'before': past and future are relative and not absolute as in a linear conception of time in which each event is unique and unrepeatable. A cyclical representation of time, which is considered typical of the ancient civilizations, is certainly related to the observation of repeating natural phenomena like the succession of night and day, of the seasons and the regular movement of the stars. Nevertheless, the linear conception of time is equally fundamental in myth (Giannetto, 2005; Von Franz, 1992), at least in the written codification of it. The first images of this double representation of time can be probably found in the hieroglyphic language of the Egyptian civilization, in which there are two complementary representations of time: one linear, connected to the hieroglyphs 'at' and 'jet', and one cyclical-circular denoted by the hieroglyphs 'ter' and 'neheh' (Giannetto, 2005). In the mythical tradition of ancient Greece, as well as in the successive philosophical and scientific thought of the classic Greece, the cyclical-circular representation of time is predominant (with the significant exception of the time of the tragedy), whereas in the Jewish and Christian tradition the linear representation of time and eternity becomes central.

Among the natural phenomena from which the mythical representation of time is derived, the regular movement of the starry sky is probably the most important one. In most of the ancient civilizations the earliest mode of telling time was based on nocturnal and lunar periodicities[2] (Gebser, 1985), and the first trails of astronomical observations can be date back to 16-20.000 years ago. As Guy Trévoux noted (Quoted in Giannetto, 2005, p. 21):

"La prima divinità suprema sarebbe stata identificata con la luna. In effetti essa regola le maree, il mutamento del tempo, il movimento della linfa nei vegetali, provoca il ciclo mestruale delle donne, gli eccessi d'umore negli esseri umani e negli animali, ma, soprattutto, questo corpoceleste è in grado, nelle eclissi, di oscurare il sole, ma non può avvenire mai il contrario".[3]

But the ancient knowledge of the sky extended way beyond the observation of the movement of the moon or the sun:

"Ogni visione apocalittica è un modo di ricongiungere la fine al principio, onde il tempo riacquisti un senso. Vi fu sempre l'idea di un grande anno, del rivolgimento della macchina del tempo, ad acquaetare le menti. In quell tempo tutto tornava, non dico nel senso letterale dell'Eterno Ritorno, ma delle costanti dell'avventura umana […] Le grandi crisi che scandivano

[2] Vestiges of this early time-reckoning practice can be found in modern languages: English for example speaks of a *fortnight* for 14 days, and *sennight* for 7 days; In German we have *Fastnacht*, "Shrove Tuesday", and *Weihnacht* "Christmas". (Gebser, 1985)

[3] "The first supreme deity was identified with the moon. In fact, it regulates the tides, the change of time, the movement of sap in plants, causes the menstrual cycle of women, the excesses of mood in humans and animals, but, more importantly, this celestial body is able, in the eclipses, to overshadow the sun, but the opposite can not ever be." (our translation)

il ciclo eterno si pensava avessero luogo ogni volta che il sole equinoziale entrava in una nuova costellazione, di cui be Quattro si sono succedute da che l'uomo ha coscienza del tempo […] il tempo in cui i punti equinoziali si trovavano sulla via lattea, […] sembra essere stato il momento d'origine scelto per il computo del tempo: e che fu verso il 5000 a.C. La via Lattea diventava il ponte tra il cielo e la terra, e ai Quattro capi (solstizi ed equinozi) si trovavano le quarto figure bifronti significanti l'immortalità: Sagittario, Gemelli, Pesci, Vergine con spica […]"[4] (De Santillana, 1985, p. 82)

Giorgio de Santillana and Hertha von Dechend (1969) have convincingly shown in their cutting-edge book "The Hamlet's mill" that many ancient civilizations, from the Yucatan Peninsula until the Indo-gangetic basin, passing through the Mesopotamian city-states, knew the phenomenon of the precession of equinoxes.[5] And they based a great part of their mythology and their comprehension of time upon this and other celestial phenomena.

It could seem preposterous to attribute such a deep and complex astronomical knowledge to this ancient population, and even more to associate celestial events with mythological stories, which were basically the religious beliefs of the people. How could most of them comprehend their astronomical basis? How could they see the representation of time (and of life and death) in the Milky Way?

This could seem strange for a culture like the modern occidental one, for which the astronomical knowledge has very little importance, but it wasn't like this for ancient people. In classical Greece the *cosmos* was perfectly intelligible to the common sense.

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[4] "Each apocalyptic vision is a way to reunite the end to the beginning in order to make the time regain sense. There was always the idea of a great year, the upheaval of the time machine to quieten minds. At that time, everything came back, I do not say in the literal sense of the eternal return, but in terms of the characters of the human adventure [...] The great crises that punctuated the eternal cycle is thought to take place whenever the equinoctial sun entered a new constellation. Four of them have occurred from when man has consciousness of time [...] the moment in which the equinoctial points were all on the milky way, [...] seems to have been the original moment chosen for the computation of time: and that was around 5000 BC. The Milky Way became the bridge between the sky and earth, and at the four corners (solstices and equinoxes) there were the fourth bifrons figures, signifying immortality: Sagittarius, Gemini, Pisces, Virgo with the spica [...] " (our translation)

[5] The precession of the equinox is the apparent movement of the starry vault due to the rotational movement of the heart axis around the perpendicular of the ecliptic. This phenomenon causes the slow change of position of the constellations in the sky, and also the position of the celestial poles, so that, for example, in 13,000 years the pole star will be Vega instead of Polaris. Each constellation will return to the same place each 26,000 years, the length of the Platonic Year (a complete precession).

The stars are grouped into constellations and those are grouped into cycles that narrate myths. The sky was like an enormous public illustrated book, and the Greeks, from the farmer to the philosopher, were used to reading the story of their origin in the sky as we would read a comic book.[6] And the same, according to de Santillana, happened in the ancient great civilizations that preceded classical Greece. Explaining this incredible interest in the stars and their motion is easy, considering that these people had localized the deities who determine the destiny of the universe and of each man in stars and planets. That for the ancient people the gods were the planets is also written by Aristotle in his *Metaphysics* (1074 b12).

According to Giannetto, the time of myth (across many ancient civilizations) was something concrete and visible. In many cases time was the Milky Way itself, sometimes observed as a circular structure (the wheel of time), and sometimes as a straight line, as a bridge between the heart and the sky, a bridge toward the eternity (immutability) of the fixed stars. The two most notable of these representations are the conception of time as the 'time of life' (the vital substance that ceases with death), and the identification of the 'flow' of time with the concrete and visible 'flow' of the stars. As the principle of life, or as a visible celestial configuration like the Milky Way, time can become personified as a deity, but it is still quite different from an abstract homogeneous medium, a product of the mind/soul or an inner sense. This peculiar conceptualization is still present in classical Greece, with the beginning of philosophy and science, in the passage from the *mythos* to the *logos*. We can find it, for example, in Plato (see next chapter) who also identified time (*chronos*) with the motion of the stars. It is through a thousand-year process of abstraction that we arrived at a concept of time like an infinite, homogeneous, running river, which exists independently of the events that it contains.

What these mythical and religious representations can teach us about our psychological experience of time? About our philosophical and scientific understanding of it? They might be useless to understand the cognitive processes which underlie our temporal reasoning and representations: the way we can distinguish the past from the

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[6] See "Variazioni sul tempo. Introduzione", *University of Calabria*, at: http://mondoailati.unical.it/corsi/istfisica/archivi/variazionisultempo/tempo_dei_greci/greci_01.htm

future, how we can estimate the length of one event compared to another, or our representation of the succession of the events, in three words, our "sense of time."

We might think that even if ancient people talked about celestial events in a way which is different from our own, they looked at the sky in the same way we look at it: physiologically, using the same retinal apparatus; cognitively, with the same distinction between figure and background, movement detection, *gestalt* of spatial configurations etc. Similarly, independently of the way a particular culture represents the idea of time, as a serpent who bites his tail, the Milky Way or a river in a flood, its perception, the experience of the flowing of time from the past to the future, of the duration of events, have remained the same in the last 40,000 years. Such a point of view is indeed based on the conception of time as a sort of inner sense, for which our 'psychological time' is the representation of the 'physical time' made possible by dedicated physiological and cognitive processes.

This work will challenge the metaphor of the experience of time as a 'sense,' and will show how the way we talk about time, and the cultural practices and beliefs that underlie its representation, can tell us a lot about the way we process and conceptualize temporal relations. Moreover, we will show how cultural and linguistic aspects of our temporal knowledge can significantly influence and shape the cognitive processes that are at the basis of our temporal thinking. In particular, we will support the thesis according to which our concept of time is based on the more primitive concept of space. We will show how a theoretical and epistemological spatialization of time is at the basis of its representation in occidental philosophy and science. This process of spatialization is necessary to measure time as a physical variable, but it is also at the basis of most of the contradiction that philosophers have faced trying to understand the nature of time and our comprehension of it: we can think for example of the paradoxes of the Heleatics and the "I don't know" of St. Augustine. But, more important, it is that even our private, psychological experience and conceptualization of time is based on the conceptual recycling of more basic spatial features and relations. Contrary to the Kantian hypothesis that space and time are two independent *a-priori* forms of intuition, we will claim that we need space to think about time, and that many of our temporal concepts are based on spatial mental metaphors which are a product of experience (sensory-motor, cultural, linguistic) and not an *a-priori* category or an innate sense.

# 2. The experience of time

Time is an illusion. Lunchtime doubly so.

*Douglas Adams*

Man lives in flux: he experiences change in nature and in himself, biologically and psychologically. But, among all creatures, man is the only one that knows he is experiencing change. As we have seen, the concept of time (the passage of time) has become more and more abstract with the evolution of civilization, being progressively detached from the natural phenomena that change periodically (See former chapter). Whether an abstract idea of time emerged for a former concrete referent or “dès l’origine […] le sens concret a été lié au sense abstrait” (Fraisse, 1967, p.1) is still under debate. And we hope to provide here some arguments that will shed a little bit of light on this process of abstraction.

Indeed, since the idea of time has become more and more abstract, philosophers have been engaged with it for a long time, usually less interested in its origin and story, and more interested in the reality to which this idea can correspond, or the way the mind/soul can generate it. Probably one of the most compelling problems about the concept of time in the western philosophical thought is exactly the problem of correspondence: does time exist by itself, independent of everything else? Or does it need a soul (human mind) that can think it, that can put together the past and the future, that can experience the perpetual change? And, if time exists by itself, is our experience of it a faithful representation?

From the beginning of philosophy in ancient Greece, men have argued over these questions and many others. A deep inquiry into the approaches that in the last 2000 years have characterized philosophical reflection on time it will probably require half a dozen doctoral theses in order to be nearly sufficient. Almost all philosophers have thought, some more than others, about the problem of time, and similar questions also arose with the birth of the natural sciences. The reason why time has interested so many bright minds in the past and still does without showing any sign of stopping (in spite of the little progress achieved in 2000 years of philosophical and scientific thinking!) is an important question, and not just a simple curiosity; we will address it more seriously at the end of this work.

In the review that follows, as in the historical discussion in the previous chapter, it is important not only to know what Plato, Aristotle and others thought about time, but to understand how we arrived to define the questions that we are now asking about time. This is very important, because if it's true, as Silvio Ceccato said, that the act of comphrehension proceeds through distinctions (and distinction of distinctions), the questions posed by Giannetto, concerning the history of physics, make a lot of sense:

> "Fin dove risalire, allora, per scorgere le origini della fisica? Molti corsi di storia partono da Galilei per caratterizzare la nascita della fisica come disciplina separata dalla filosofia, "scientifica". Ma è realmente possibile comprendere la fisica di Galilei senza confrontarla con la fisica medievale e aristotelica rispetto alle quali si è differenziata? Ed è possibile comprendere la fisica di Aristotele senza confrontarla con la fisica di Platone e con quella pre-socratica, rispetto alle quali si è differenziata costituendosi? Ed è effettivamente possibile comprendere la fisica pre-socratica senza tenere conto del sapere fisico-astronomico di cui è pure piena la mitologia?" (Giannetto, 1998, p. 3)[7]

The importance of following as much as possible the history and evolution of a concept, and the related problems, is even more important for sciences like psychology where too often what we call, for example, 'time' is treated like "un oggetto freddo e a-storico che cadrebbe nei laboratori come dal cielo"[8] (Latoure, 2005).

Recently, Giovanni Bruno Vicario (Vicario, 2005), in his book "*Il tempo. Saggio di psicologia sperimentale*." had proposed a brief but cogent review of the most important philosophers that had contribute to the definition of the 'problem(s) of time' as we know it today. The choice of the authors and the focus on the arguments proposed by Vicario, though probably usatisfactory for a philosophical historical review, is surely

[7] How far back, then, to discern the origins of physics? Many history courses start from Galilei to characterize the birth of physics as a discipline separate from 'scientific' philosophy. But is it really possible to understand the physics of Galileo without comparing it with medieval and Aristotelian physics from with it has been differentatated? And can we understand the physics of Aristotle without comparing it with the physics of Plato and the pre-Socratic? And is it indeed possible to understand the pre-Socratic physics without taking into account the physical and astronomical knowledge that we find into mythology? " (our translation)

[8] "an object cold, and without story, that falls into laboratories as from the sky" (our translation)

adequate for a discussion on the problem of time in terms of epistemology, cognitive psychology and linguistic anthropology. Vicario highlighted the evolution of the philosophical questions about time that will be important for the epistemological and methodological approach that we present in this work; for this reason is convenient to follow it. Moreover, at the same time we will follow the historical reconstruction of the notion of time and temporality provided by Gianetto (1998; 2005), with a particular focus on the progressive 'spatialization' of time that has characterized its representation across history and philosophical schools and that can be traced back to the separation from *mythos* and *logos* at the beginning of classical Greece. The crib of the modern philosophic and scientific thinking.

## 2.1 Plato

In the *Timaeus*, Plato writes:

> "Now the nature of the ideal being was everlasting, but to bestow this attribute in its fulness upon a creature was impossible. Wherefore he resolved to have a moving image of eternity [*aióon*], and when he set in order the heaven, he made this image eternal but moving according to number, while eternity itself rests in unity; and this image we call time [*chrónos*]." (Timaeus, 37d-38c)

According to Plato time is something that exist 'by itself', a natural kind. But a natural kind of second order as Vicario remarks, because it derives from another time, the time of eternity, of which it is a 'moving image'. In these terms the perspective of Plato is precursor of the Newtonian division between the *absolute time*, those of the physic, and the *vulgar time*, that we use everyday and that is marked by our, imperfect, instruments of measure (see 2.5)

In a recent writing, Claudio Tugnoli (2001), reports a beautiful quotation by Jean Guitton: "se è vero che l'intelligenza và alla ricerca di rapporti immutabili, perciò sottratti al divenire, il tempo dovrebbe coerentemente svanire man mano che l'intelligenza lo rischiara”.[9] Among the philosopher that we will consider in this brief presentation, Plato is the one that is still more close to the transition from the *mythos* to the *logos*. The lightning analysis by Jean Guitton is successfully applicable to this transition in which, as sustained by Giannetto, we assist to a:

> “progressiva perdita reale del senso del tempo nella transizione da una ‘percezione temporale-spirituale’ del mondo e della vita, ad un ‘pensiero astratto spaziale-materiale’” (Giannetto, 1998, p.17)[10]

It is in the light of this important transition that we should consider the Platonic writings, and his conception of time. A brief digression in this direction will help us in the understanding of the platonic philosophy.

The discourse around the nature and the human conditions (*physis*) in the *mythos* and even at the beginning of the Greek philosophy was intimately linked on the experience of the *kinesis*, and of the *metabolé*, meaning change (Giannetto, 1998). The problem, therefore, is that the continuous and undetermined change challenge any kind of conceptualization, and frustrate any effort to anchor it at any logical or onto-logical statute. Anassimandro characterized the nature (the physis), as *apeiron*, illimited, undetermined, and according to Giannetto:

> “L'*apeiron* non è altro che la caratterizzazione di tale mutamento che ha una intrinseca dimensione temporale, del tempo come *aiòn,* l'*apeiron aiònios*. I mondi e tutto quanto è parte della natura hanno la loro origine, derivano, sono costituiti di mutamento, di tempo. Il tempo non è altro che questo fluire infinito, non materiale, e che si potrebbe caratterizzare come 'etereo', di luce. La natura in quanto indeterminato mutamento temporale non può quindi essere 'oggetto' di conoscenza o scienza alcuna.” (*ibid*. p.18)[11]

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[9] “If it’s true that intelligence seeks for immutable relations, therefore subtracted to the becoming, time should coherently disappear as intelligence make it clear” (our translation)

[10] “progressive loss of the sense of time in the transition from a ‘temporal-spiritual perception of the world and life, to a ‘abstract spatial-material though’ of it ” (our translation)

[11] “The *apeiron* is nothing but the characterization of this continuous change which has an intrinsic temporal dimension, of time as *aiòn*, the *apeiron aiònios*. The worlds and anything it’s part of nature have their origin, derived, are built out of change, of time. The time it is nothing but this infinite flow, non material, and that it may be described as ‘ethereal’, of light. The nature, insofar as un-determined temporal change cannot be ‘object’ of knowledge or science” (our translation)

In this view, time is identified with the continuous flux of change from which everything has origin. The un-ending *becoming* of the reality. Nevertheless, given this continuous change, in which never is the same twice, and nothing is the same to itself in a certain moment (because you can't stop the flux to look at something in a certain moment!) it is impossible to conceive an ontology (i.e. basic cathegorries of *being*) or a logic (say, A=B) to describe the reality.

A first solution of the problem, in which we can find, according to Giannetto, the turning point that represents the foundation of the ancient science, can be found in the radical theory of Parmenides. The mystique approach of Parmenides is based on a radical negation of change, and consequently, of time. Time and change are not real, but just an illusion of our senses, an illusion that can drive our reasoning to non-logic conclusion like the continuous transition from 'to be' to 'not to be', from existence to non-existence, and vice-versa, without any chance of 'being something in a determined moment'. But, since the 'not being' does not exist ('it is not'), the transition between 'being' and 'not-being' is impossible (that's, roughly speaking, the principal argument of Parmenides),[12] than *change* is impossible, and *existence* is timeless, uniform, and unchanging.

The hypostatization of being, and the relativity of change and motion (in terms of negation of his actual reality), operated by Parmenides has strongly influenced the course of Greek philosophy constantly engaged in recomposing the opposite philosophies of *being* and *becoming*. And to this effort is oriented the Platonic *Timaeus*.

According to Giannetto, Plato

> "ha cercato anch'egli di ricomporre essere e divenire, riducendo nuovamente il divenire all'essere accessibile alla scienza: come notato esemplarmente da Heidegger, la natura è stata ridotta ad immagine-rappresentazione ontologica di un ideale mondo vero, matematico e atemporale." (*ibid* p. 19)[13]

[12] From here the conclusion that time is apparence, because its existence entail the 'becoming' of the events, therefore a prepostherous passagge from the preceeding 'not-being' (the future 'is not', not yet) to the following 'being' (the present).

[13] "has tried himself to recompose being and becoming reducing again the becoming to the being, the only one accessible to science. As Heidegger has noted, nature has been reduced to an

The concept of time of Platonic derivation, *chronos*, conceived as "mobile image, cyclic, according to number", it is indeed an image, a surrogate of time as duration infinitely extended and motionless (eternity itself rests in unity) of the true ideal world. *Chronos* is the mobile image of *aiòn*, the eternity, the infinite and changeless, the time of the being (of the existence).

Giannetto writes:

"L'immagine platonica, a mio avviso, va interpretata come icona analogica definita da una proporzione all'interno della teoria fisico-matematica delle (proporzioni tra) grandezze omogenee, sviluppata soprattutto da Eudosso e Teeteto: il divenire non è che il ripetersi molteplice dell'essere, a cui come tale è omogeneo; ovvero l'essere è l''unità di misura' del divenire, in quanto *chronos* misura il divenire quale ripetersi molteplice dell'unità di misura dell'essere come estensione unitaria che è l'*aiòn*, come 'eone cosmico', così partecipando analogicamente ad esso cui è omogeneo." (*ibid*. p.19)[14]

The Platonic *chronos* is an analogical icon, a logical and mathematical expedient to overcome the problem of the incommensurability between 'being' and 'becoming'.[15]

The Platonic view imply, according to Giannetto, a cosmic determinism connected with an eternal cycle (the cyclicar representation of time, typical of the

ontologic image-representation of an ideal true world, a-temporal and mathematic". (our translation)

[14] "The Platonic image, in my view, has to be interpreted as an analogical icon defined by a proportion in a physical-mathematical theory of (proportion between) homogeneous magnitudes, developed especially by Eudosso and Teeteto: the becoming is nothing but the multiple repeating of the being, to which, therefore, is homogeneous; the being is the unit of measure of the becoming, so that *chronos* measures the becoming as multiple repetition of the unit of measure of existence (being), the aiòn, which is a unitary extension, a 'cosmic eon', participating analogically to which it is homogeneous" (our translation)

[15] Curiously, Galileo Galilei was facing a similar problem when he wasn't able to put in a rapport space and time, two non-homogeneous magnitudes (see Bellone, 1994 and paragraph 2.5 in this chapter); a problem that, as we will see, has been resolved by Newton with the help of infinitesimal calculus and the *ad hoc* distinction between *vulgar time* and *absolute time*. A distinction similar to the Platonic one between *chronos* and *aiòn*, as already noted by Vicario.

ancient Greece) in which different ‘aiòns’ (temporal intervals), are reduced to a unique *aiòn* equally repeated in the ordinate series that determine the *chronos*.[16]

This spatialization of time appears more clear in the Parmenides, the dialog in which Plato extends the range of Zeno’s paradoxes from movement to time. Here Plato invents the notion of ‘moment’ (*exaiphnes*) as a-temporal part of *chronos* where the event of change takes place:

“The moment. For the moment seems to imply a something out of which change takes place into either of two states; for the change is not from the state of rest as such, nor, from the state of motion as such; but there is this curious nature, which we call the moment lying between rest and motion, not being in any time; and into this and out of this what is in motion changes into rest, and what is at rest into motion.

So it appears. And the one then, since it is at rest and also in motion, will change to either, for only in this way can it be in both. And in changing it changes in a moment, and when it is changing it will be in no time, and will not then be either in motion or at rest. “ (Plato, *Parmenides*)

As the movement of the arrows, in the Zeno famous paradox, can be reduced to a series of instantaneous static positions (because movement and time are considered divisible like space), the flux of time as continuous change has its origin in non-

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[16] This conceptualization of time cannot be fully understood without considering the Platonic cosmology and especially his understanding of the astronomical events (Giannetto, 2005; De Santillana, 1969). Cosider this quotation from the Timaeus:

“Time, then, and the heaven came into being at the same instant in order that, having been created together, if ever there was to be a dissolution of them, they might be dissolved together […]The sun and moon and five other stars, which are called the planets, were created by him in order to distinguish and preserve the numbers of time; and when he had made-their several bodies, he placed them in the orbits in which the circle of the other was revolving-in seven orbits seven stars […]Now, when all the stars which were necessary to the creation of time had attained a motion suitable to them,-and had become living creatures having bodies fastened by vital chains, and learnt their appointed task, moving in the motion of the diverse, which is diagonal, and passes through and is governed by the motion of the same, they revolved, some in a larger and some in a lesser orbit-those which had the lesser orbit revolving faster, and those which had the larger more slowly.”

And the interpretation given by de Santillana:

“Eternity abides in unity highest and farthest "outside." Within, Time, its everlasting likeness, moves according to number, doing so by means of the daily turning of the fixed sphere in the sense of "the Same," the celestial equator, and by means of the instruments of time, the planets, moving in the opposite direction along "the Different," i.e., the ecliptic” (De Santillana, 1969, p. 308) temporal moments, because the intermediate state between quiet and movement is out of time. Therefore, the *becoming*, which is exactly the transition from quiet to movement and from movement to quiet, doesn't happen in time, but in the moment, which is a-temporal.

We can glimpse here the transition between *mythos* and *logos*, in which the temporal diversity and heterogeneity of the continuous change is reduced to a quantitative and divisible extension through spatial analogy. A spatialized time which is the precursor of the mathematical reduction of time to extension, pointed out by Bergson, that characterized most of the modern scientific and philosophic tradition in the western world.

## 2.2 Aristotle

According to Aristotle, time is

> "a number of change with respect to the before and after" (*Physics*, 219,b).

the word *metabolée* (change) has in Aristotle different meanings, like the corruption and generation of a substance, the change in quality and quantity, and movement from one place to another. According to Aristotle, everything that is natural is subject to change (in this broad sense), and time is the measure of this change. Then, we could suggest that time, for Aristotle is a natural kind as for Plato, but, instead of being derived from a more pure 'idea' of time, it is derived from the perception of the more basic phenomenon of change. Time exists because change exists, and not vice versa.

On the other hand, Aristotle was fully aware of another problem, so that if time is essentially countable, because it is "a number of change", it means somehow that time is dependent upon a mind (or, better, a soul) who can count:

> "Whether if soul did not exist time would exist or not, is a question that may fairly be asked; for if there cannot be some one to count there cannot be anything that can be counted, so

that evidently there cannot be number; for number is either what has been, or what can be, counted. But if nothing but soul, or in soul reason, is qualified to count, there would not be time unless there be soul, but only that of which time is an attribute, i.e., if movement can exist without soul, and the before and after are attributes of movement, and time is these *qua* numerable" (*Physics* 4.14 223a)

We should precise that the property of time to be "a number of change" doesn't refer to the natural numbers or to a mere quantification, but to the notion of order, or cardinal numbers (Giannetto, 1998). The emphasis on the notion of order has been stressed also by Coope (2005) when she remarks that Aristotle used "number" (*arithmos*) rather than "measure" (*metron*), exactly because counting is manly a way of ordering, and time for Aristotle is a type of order (Coope, 2005).

The emphasis on the ordinality, presumably referred to discrete entities, should drive our attention to the spatial analogy on which time has been represented as an extension in the Platonic philosophy. According to Giannetto, indeed, Aristotle "has reduced *change* to an extension from something that exists to something else that exists, on the basis of a spatial analogy".[17] Even the substantial changes, like corruption and degeneration, described above can be reduced to this spatial analogy ('from x' – 'to y'). Indeed *change* (metabolée) refers to a variation of states of the existence that can be discretized and somehow isolated from the whole. This appear clear if we know that Aristotle assigned to change, and in particular to motion, a minor degree of 'reality', an existence *in posse* (potential) but not *in esse*.[18] The status of quiet, without motion, is considered as basic. And motion is the repetition of different states of quiet (Giannetto, 1998). Nevertheless, for Aristotle time is not absolute and independent of change and movement, as it was for Plato (and as it will be for Newton), but is inherent to them, in the sense that there is not time without change.

But Aristotle knows that time can be defined and measured only on the basis of a change that is homogeneous and regular. Giannetto writes:

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[17] Our translation from the original Italian: "ha ridotto il mutamento ad estensione da qualcosa che è a qualcos'altro che è, sulla base di un'analogia spaziale"
[18] Because movement in the Aristotelian physics needs a 'cause'.

"così Aristotele lo definisce a partire dal solo moto locale che abbia queste particolarità: il tempo (ciclico, circolare) è il moto locale celeste, rotatorio-circolare, uniforme ed eterno, dell'ottava sfera del cosmo o 'primo mobile' in cui sono incastonate le stele fisse. Il tempo è concepito come 'numero del movimento secondo il prima e il poi' ovvero come numero ordinale che è misurabile come moto locale ridotto a cambiamento di posizione attraverso un confronto di estensioni spaziali, e che è misura del moto."[19] (Giannetto, 2005, p. 86)

Even if, for Aristotle, motion is a continuous and non-separable extention (Giannetto, 2005), the fact that it is measurable (according to the before and the after), imply that it can, potentially, be devided in infinite present-instants, *nyn*, which are out of the time like the Platonic 'moments'. In the present-instant, which is the connection between quiet and change, which is part of an extension but it is without extension, which is devided but not-separable, which is out of the flux but is where the flux happens, is concealed and unsolved the mistery of time (Giannetto, 2005).

Besides its unsolved contradictions, we could say with Giannetto that for Aristotle, time, as number and measure, is conceived as an extension, compared with the time of the motion of the fixed stars, and based on a spatial analogy according to which:

- the becoming is reduced to different states of quiet of a being that is permanently present.
- and time is conceived as the ideal succession of present-instants.

There is nothing like the infinite, changeless and motionless Platonic *aiòn*, if not in the instant itself, which can be compared to the eternity because eis out of time (Giannetto, 2005). On the other hand, time is also inherent to the soul (mind), so that Aristotle ask himself if time can exist without a soul that measure it, because "if there cannot be some one to count there cannot be anything that can be counted". Aristotle

[19] Therefore, Aristotle defines it on the basis of the only local motion which has these peculiarities: time (cyclic, circular) is the local celestial motion, rotating and circular, uniform and eternal, of the eighth sphere of the cosmos, the sphere in which are set the starry stars. Time is conceived as 'number of change (metabolée) with respect to the before and after' that is, as ordinal number which is measurable as local motion reduced to a change of position through a comparison of spatial extensions, which is the measure of motion." (our translation)

does not give an answer to this problem, that will become one of the major problems in the philosophy of time.

## 2.3 Plotinus

Plotino di Licopoli has been included in this list of philosophers because is the first that clearly conceive time as a product of the spirit (Vicario, 2005):

> "L'anima non presenta il proprio atto se non in momenti successivi: prima l'uno, poi l'altro e poi un terzo, nuovamente, in serie: essa genera di pari passo, con la sua operazione, il concatenamento temporale, e mentre un pensiero si accende su un altro pensiero, avanza ciò che prima non era, perché il pensiero non si è realizzato nell'atto puro, e così neppure la vita di ora è simile alla precedente. Di pari passo il vivere si rinnova, e proprio quel suo rinnovarsi si carica di tempo nuovo. Questo presentarsi della vita, pezzo per pezzo, separatamente, è carico di tempo; questo ulteriore 'sempre' della vita s'addossa sempre un tempo ulteriore, e la vita trascorsa è carica pure di tempo trascorso." (Enneadi, III, 7, 106-107) (Quoted in Vicario, 2005)

Vicario remarks that the key word in this text is *diastasis* (here translated as 'pezzo per pezzo'/ 'bit by bit'), that denotes a process in successive phases. Vicario compares this term to what Augustine will call *distentio* and Husserl *protention*. It is the soul that moves, and with this movement produces the time (Vicario, 2005). In modern terms we could say that time is a projection of thought, in the sense that it is not intrinsic in any natural phenomena, and neither it can be derived from more basic natural phenomena or abstracted from them in the interaction between the mind (spirit, subjectivity) and the world (nature, objectivity). We don't need the external world, or the natural process of change in order to experience time (in fact we are still experience time even without any objective change), because the 'before' and 'after' is a product of the soul.

It is important to precise, nevertheless, that the 'soul' to which Plotino refers when he uses the term *psychée*, is a universal soul, the *world soul*, and not the individual soul. Without going too much into the argument (that we will approach more deeply talking about Augustine, in the next paragraph) the world soul is the vital principle from which everything that is matter derives. Nevertheless, Vicario suggests that, according to Plotinus, the individual soul is conform to the universal soul, and follow the same process:

> “Tempo, pure in noi uomini? Ecco, esso è nell’anima universale, così come l’abbiamo descritta; ed è, in egual forma, in ogni anima…” (Ibid. III, 7, 143)

## 2.4 Augustine

It is not even thinkable to present an historical review on the philosophy of time, however brief, without considering the enormous contribution given by Agostino d’Ippona, better known as Augustine. Augustine is usually known because he introduced the idea of time as product of the soul, a subjective perspective perhaps in contrast with an objective point of view, dominant in the ancient Greece after Aristotle. We have seen how this idea of time as an extension of the soul was already present in Plotinus, but that doesn’t affect the originality of the Augustinian writing.

Augustine, in the book XI of the confessions writes:

> What then is time? If no one asks me, I know: if I wish to explain it to one that asketh, I know not: yet I say boldly that I know, that if nothing passed away, time past were not; and if nothing were coming, a time to come were not; and if nothing were, time present were not. […]Whence it seemed to me, that time is nothing else than protraction; but of what, I know not; and I marvel, if it be not of the mind itself? (Confessions, Book XI, 26, 33)

According to Vicario, one of the most important differences between Augustine and Plotinous stand in the use of the term *distentio* that denote a continuous movement and not a discontinuos one, as the Plotinian *diastasis* (discontinuity that can be inferred by the presence of the lemma *stasis*, embedded in the word). This emphasis on the continuity, on time as a process instead of an extension, can be interpreted, in our opinion, as a sign of a progressive de-spatialization of time, a negation of time as an homogeneous extension that has been the presupposition to the cyclical conceptualization of time in the ancient Greece, and that it is still present in the Plotinian *diastasis*.

Moreover, Vicario remarks that:

"la *distentio* di Agostino è attribuita all'animus, non all'anima – cioè allo spirito, e non alla sostanza vitale. Aristotele su questo punto è incerto: come abbiamo visto, non sa se il numerare è da attribuirsi alla *psychée* (in latino: *anima*) o al noùs (in latino *animus* o *intellectus*) che è nella *psychée*. Mettendola in termini aggiornati, la *distention* non sarebbe un processo di basso livello, biologico o neurofisiologico, ma di alto livello come la percezione o il pensiero." (Vicario, 2005, p. 28)[20]

Nevertheless, Giannetto does not completely agree with the main stream in the Augustinian studies, in which Augustine is described as the "discoverer" of the subjective dimension of time, as the 'time of the soul' (like the Bergsonian *duration*). According to Giannetto the main stream seems to ignore the influence of the original Christian cosmology on the Augustinian writings:

"Nell'accettazione di questo punto di vista dominante si è già persa la percezione della specificità dell'esperienza cristiana, e in parte ancora agostiniana, di una temporalità originaria che non è riducibile ad una qualsiasi connotazione soggettivistica o oggettivistica del tempo, in quanto propria di una vita che non teoreticizza astrattamente una separazione soggetto-oggetto di conoscenza, una separazione della vita dalla natura, e in cui, come già detto, tempo della vita e tempo del mondo coincidono" (Giannetto, 1998, p. 25)[21]

Moreover, Giannetto somehow disagree with Vicario who attributed the 'distentio animi' to high processes of thought:

[20] "The Augustinian *distentio* is attributed to the *animus*, not to the *anima* – namely to the spirit, not to the vital substance. Aristotle was uncertain concerning this issue: as we have seen, he did not know if the counting had to be attributed to the *psycheé* (in Latin: anima) or to the *noùs* (in Latin: animus or intellectus) which is in the psychée. To put it in more updated terms, the distentions wouldn't be a low level process, biological or neuro-physiological, but a high level process as perception or thought." (our transaltion)

[21] Accepting this dominant point of view we have lost already the perception of the specificity of the Christian experience, and in part, still Augustinian, of a temporality that is not reducible to a subjective or objective connotation of time. A temporality of a life that do not theoriticize abstractly a subject-object separation of knowledge, a separation of life from the nature. A temporality in which time of life and time of the world coincide" (our translation)

"e ancor di più non è riducibile a tempo della coscienza, in quanto proprio di una vita nella natura che autocomprende il mondo del sé come non teoreticamente e astrattamente separato in conscio e inconscio." (*ibid.* p. 25)[22]

Giannetto refers to the characteristics conception of time of the first Christian communities, a Christianity essenic, pre-apostolic, pre-nicene, that haven't yet been subjected to the process of hellenization typical of the late Christianity that we all know. We won't stay more on this complex argument (see Giannetto, 1998, 2005), but, it is worth remembering briefly that whether, usually, the linear conception of time typical of the Jewish-Christian tradition is opposed to the cyclical representation of the ancient Greeks, this is not the only important difference. The features of a de-spatialized, non-homogeneous and non divisible, intensive and qualitative temporality, professed by the original Christianity, will emerge in the proceeding of the discussion of the Augustinian philosophy and, more important, it will elicitate some of the crucial problem that, not only philosophers and psychologists, but also physicists and mathematician had to face in the effort to understand the phenomenon of time and temporal experience.

Concerning the dilemma about the objective or subjective ontology of time, according to Gianetto, it is in the *De musica* that we can find the clues of a non-purely subjectivistic connotation of time in Augustine:

"nisi quia unicuique animanti in genere proprio, proportione universitatis, sensus locorum temporumque tributus est; ut quomodo corpus ejus proportione universi corporis tantum est, cujus pars est, et aetas ejus proportione universi saeculi tanta est, cujus pars est; ita sensus ejus actioni ejus congruat, quam proportione agit universi motus, cujus haec pars est"[23] (Augustine, *De musica*, VI, 7, 19)[24]

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[22]Moreover, it is not reducible to the time of consciousness, because belong to a life of nature which auto-include the world of the self as non theoretically and abstractly separated in conscious and unconscious. (our translation)

[23] "… to each living being, among his species, has been done, in proportion with the whole, only the sensible intuition of space and time. Therefore, as his being extended in proportion to the wholeness of space is finite, because he is a part of it; in the same way, his existence in proportion to the wholeness of time is finite, because he is a part of it. Therefore his sensible intuition should be commensurated to the movement that performes in proportion to the movement of the whole, to which it is part." (our translation)

[24] But see also, De Musica, VI, 8, 21; VI, 11, 29; VI, 17, 57.

According to Giannetto, here emerges the connotation of a nature characterized by a 'temporal soul', a *distentio animi* that should be read in psychics, spiritual (and cosmological) terms instead of subjective psychological terms.

"Non è che il tempo sia legato essenzialmente all'anima umana, ma piuttosto il tempo, il numero come tempo è, pitagoricamente ed essenamente, l'anima di ogni cosa" (Giannetto, 1998, p.26)[25]

According to this view, in the expression "distentio animi" the genitive is not 'objective' but 'subjective': the *distentio*, that is time, it is not possessed by the soul (the human soul), but is itself the soul of the things of nature[26] (Giannetto, 1998). It is worth to remark that Augustine talks about "the number of time" as the soul of everything. The Augustinian interest is focused on the measurement of time, and in the use of time as a measure of something else (motion, for example). Indeed, it is facing the spectrum of the impossibility of an absolute measure of time that generates the famous "I don't know", suggesting that time might be a *distentio animi:*

"**Does not my soul most truly confess unto Thee, that I do measure times? Do I then measure, O my God, and know not what I measure?** I measure the motion of a body in time; and the time itself do I not measure? Or could I indeed measure the motion of a body how long it were, and in how long space it could come from this place to that, without measuring the time in which it is moved? This same time then, how do I measure? do we by a shorter time measure a longer, as by the space of a cubit, the space of a rood? for so indeed we seem by the space of a short syllable, to measure the space of a long syllable, and to say that this is double the other. Thus measure we the spaces of stanzas, by the spaces of the verses, and the spaces of the verses, by the spaces of the feet, and the spaces of the feet, by the spaces of the syllables, and the spaces of long, by the space of short syllables; not measuring by pages (for then we measure spaces, not times); but when we utter the words and they pass by, and we say "it is a long stanza, because composed of so many verses; long verses, because consisting of so many feet; long feet, because prolonged by so many syllables; a long syllable because double to a

[25] "Time is not essentially linked to the human soul, rather, time, the number as time is, pitagorically and essenically, the soul of every thing" (our translation)
[26] Time isn't the motion of the things, but what generate the motion, the real motion in nature, time is what makes the things alive, what *animate* them.

short one. But neither do we this way obtain any certain measure of time; because it may be, that a shorter verse, pronounced more fully, may take up more time than a longer, pronounced hurriedly. And so for a verse, a foot, a syllable. Whence it seemed to me, that time is nothing else than protraction; but of what, **I know not**; and I marvel, if it be not of the mind itself? For what, I beseech Thee, O my God, do I measure, when I say, either indefinitely "this is a longer time than that," or definitely "this is double that"? That I measure time, I know; and yet I measure not time to come, for it is not yet; nor present, because it is not protracted by any space; nor past, because it now is not. What then do I measure? Times passing, not past? for so I said." (Confessions, XI, 26, 33)

According to Giannetto here we can catch the Augustinian attempt to go beyond the connotation of a measurable time on the basis of a spatial analogy. Augustine understands that the measure of time is equivalent to the measure of space just in a formal way, because is based on a confrontation with a sample magnitude (say, a human feet for space and the oscillation of a pendulum for time). But, the sample magnitude, for time, it is not given, once and for all, like a material object. But has to be continuously reproduced, without the certainty that it's identical to the previous ones. In these terms the measure of time is always inaccurate. For Augustine, the measure of time is the measure of a flux, a transition, a process, and its three dimensions, the past, the present and the future, are not susceptible of measurement like the length, width or height of a material object. Because they are not materially present. Time, as a process, is not measurable, in the sense that a physical measure of time and motion implies the destruction of time and motion themselves, their arrest, the separability in parts (ideally homogeneous) which leads to the problem of the infinite succession of immeasurable *instants* (Aristotle) or *moments* (Plato), and to the paradoxes of the Eleatics. Time is not an additive magnitude, because its parts cannot exist together, in a sum (if not metaphorically). And Augustine is aware of that:

"By plain sense then, I measure a long syllable by a short, and I sensibly find it to have twice so much; but when one sounds after the other, if the former be short, the latter long, how shall I detain the short one, and how, measuring, shall I apply it to the long, that I may find this to have twice so much; seeing the long does not begin to sound, unless the short leaves sounding? And that very long one do I measure as present, seeing I measure it not till it be ended? Now his ending is his passing away. What then is it I measure? Where is the short syllable by which I measure? Where the long which I measure? Both have sounded, have flown, passed away, are no more; and yet I measure, and confidently answer (so far as is presumed on a practised sense) that as to space of time this syllable is but single, that double. And yet I could not do this, unless they were already past and ended. It is not then themselves, which now are not, that I measure, but something in my memory, which there remains fixed." (ibid. XI, 27, 35)[27]

Are the traces in the memory the extensions of time that we make correspond to pieces of the flux of time, which we can measure. And of course it is an indirect measure. According with the interpretation given by Giannetto, for Augustine, people measure the time of things through the memory of that time in their soul, thanks to the ideal 'stops' that the memory itself allows.[28] But the psychological extension of time, in the memory, it is just the reflex of the psychic *distentio*, of time, characterized by the non-separability of past, future and present[29] (see Giannetto 1998 and 2005 for this one and further discussions).

The last important issue that we want to address concerns the relativity of time and motion. According to Giannetto, the psychic, and not purely subjective, connotation of time, that appears evident in the Augustinian writings, lead the philosopher to the conclusion that all temporal maesures are relative. Time as a measure can be used to refer to a moving object, but also to a static object, just because there will be always another body/object that it is moving. Time, as a measure, is always a relation between events:

[27] "Come manifestano i sensi, io misuro la sillaba lunga mediante la breve, sentendo che la lunga ha una durata doppia della breve. Ma una sillaba risuona dopo un'altra; se prima è la breve, la lunga dopo, come trattenere la breve? e come applicarla sulla lunga per misurarla e trovare così che ha una durata doppia, se la lunga comincia a risuonare soltanto quando la breve cessò di risuonare? e la stessa sillaba lunga la misuro quando è presente, mentre non la misuro che finita? Ma quando è finita è passata. Cosa misuro dunque? Dov'è la breve, che uso per misurare? dov'è la lunga, che devo misurare? Entrambe risuonarono, svanirono, passarono, non sono più. Eppure io misuro e rispondo, con tutta la fiducia che si ha in un senso esercitato, che una è semplice, l'altra doppia, in estensione temporale, s'intende: cosa che posso fare solo in quanto sono passate e finite. Dunque non misuro già le sillabe in sé, che non sono più, ma qualcosa nella mia memoria, che resta infisso."

[28] *Confessiones* , XI, 27, 36; XI, 28, 37; XI, 29, 39

[29] *Confessiones* , XI, 17, 22; 20, 26

"I heard once from a learned man, that the motions of the sun, moon, and stars, constituted time, and I assented not. For why should not the motions of all bodies rather be times? Or, if the lights of heaven should cease, and a potter's wheel run round, should there be no time by which we might measure those whirlings, and say, that either it moved with equal pauses, or if it turned sometimes slower, otherwhiles quicker, that some rounds were longer, other shorter? Or, while we were saying this, should we not also be speaking in time? Or, should there in our words be some syllables short, others long, but because those sounded in a shorter time, these in a longer? God, grant to men to see in a small thing notices common to things great and small. The stars and lights of heaven, are also for signs, and for seasons, and for years, and for days; they are; yet neither should I say, that the going round of that wooden wheel was a day, nor yet he, that it was therefore no time." (Confessions, XI, 23, 29)[30]

Here Augustine set against the idea of a true and unique time, aristotelically associated to the movement of certain stars, a potential plurality of time, relative to the local system of reference, a point of view that will be present later in Giordano Bruno, Leibniz and condemned to the oblivion by the Newtonian 'absolute time' until the formulation of the relativistic theories, in physics, at the beginning of the last century.

According to Giannetto, successively, Augustine will never give a definition of time that goes beyond this plurality suggesting an absolute referent in the human psychological soul, but he will just try to clarify the impossibility to determine an essential nature and a measure of time (Confessions, XI, 25, 32; 26, 33).

It is not the objective of this chapter to establish which is the most correct interpretation of the Augustinian writings, what it is important for us it is that in this

[30] "Ho udito dire da una persona istruita che il tempo è, di per sé, il moto del sole, della luna e degli astri ; e non assentii. Perché il tempo non sarebbe piuttosto il moto di tutti i corpi? Qualora si arrestassero gli astri del cielo, e si muovesse la ruota del vasaio, non esisterebbe più il tempo per misurarne i giri e poter dire che hanno durate uguali, oppure, se si svolgono ora più lenti, ora più veloci, che gli uni sono più lunghi, gli altri meno? E ciò dicendo, non parleremmo noi stessi nel tempo? e non vi sarebbero nelle nostre parole sillabe lunghe e brevi per la sola ragione che le prime risuonarono per un tempo più lungo, le seconde più breve? O Dio, concedi agli uomini di scorgere in un fatto modesto i concetti comuni delle piccole come delle grandi realtà. Esistono astri e lumi del cielo quali segni delle stagioni, dei giorni e degli anni, esistono, è vero; ma come io non oserei affermare che la rivoluzione di quella rotella di legno sia il giorno, neppure quel saggio oserà dire che perciò non sia un tempo." (Confessions, XI, 23, 29)

paragraph we have been able to elaborate two important issues and arise a third one, which are fundamental for the philosophy of time:

1) The important question about a subjective or objective ontology of time and duration, left open by Aristotle.

2) The difference between the conceptualization of time as a measurable (spatial) extension, and a non-measurable (non-spatial) process. And according to Ausustine we can measure time only thanks to the virtual arrests of the process (of time) in our memory.

3) The relativity of all temporal measure, that imply a plurality of *times*, relative to the movement of the object chosen as a referent (one "day" is 1 rotation of the heart or, say, 1000 rotation of a potter's wheel), compared to the possibility of an absolute measure that imply the existence of an absolute movement that we can call time (the movement of certain stars) or an "absolute time", like the Platonic *Aiòn* (in which 1 day is always the same temporal interval extracted from the extension of the absolute time).

Despite the influence of Augustine and the deepness of his analysis, the relativistic approach to the measure of time will be defeated by an absolute approach. An *absolute time* which will be at the basis of the Newtonian physics, and will remain the dominant paradigm in science until the last century.

## 2.5 Newton and absolute time

Newton introduced a new and important concept in the debate of philosophy of time: the absolute time. A concept destined to an enduring fame.

"Absolute, true, and mathematical time, of itself, and from its own nature flows equably without regard to anything external, and by another name is called duration: [Absolute time is to be contrasted with] relative, apparent, and common time, [which] is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year." (Newton, 1760, 12)

What appears suddenly clear from this definition is that Newton use the expression *Absolute time* to denote a *thing* that exists in the world, and it's independent from any other thing (Bellone, 1994).

We have to say that, in all the recent scientific articles, or philosophical review concerning the argument *time* that we've read, Newton's theory of absolute time is probably the most criticized and disproved, so that if every philosopher or scientist has a different theory of time, almost all of them could agree that Newton's theory of absolute time is wrong. For a series of reasons, though, it is also the most broadly accepted in the non-scientific community (or, at least, non-accademic) and apparently, many psychologists or cognitive scientists are still implicitly interpreting their findings on its basis (see Vicario, 2005).

Considering the large popularity of this theory, it is worth to try to understand the reason of this fame, maybe starting from the arguments provided by Newton itself.

Distinguishing between relative and absolute time, suggested Newton, allows for the corrections of inequalities in the solar day (the amount of time it takes for the sun to return to its zenith), which was originally thought to be uniform throughout. Astronomers can correct the equations that involve the constant *t* (the absolute time) by using natural events that are more homogeneus, like for example the sideral day (the amount of time needed for a fixed star to return to its zenith) used in Ptolemaic astronomy. Of course, also the sideral day is subject to considerable variation and has to be corrected. Even the atomic clock, the most accurate temporal measure based on the resonance frequency of a Cesium atom, nowadays used to determine the International Atomic Time, is subject to error (estimated around $10^{-9}$ seconds per day). As suggested by Augustine, among others, a measure of time is always inaccurate. Indeed, that a totally accurate measure of time was impossible was understood also by Newton:

"It may be, that there is no such thing as an equable motion, whereby time may be accurately measured. All motions may be accelerated and retarded…"

But…

“but the true, or equable, progress of absolute time is liable to no change. The duration or perseverance of the existence of things remains the same, whether the motions are swift or slow, or none at all: and therefore, it ought to be distinguished from what are only sensible measures thereof; and out of which we collect it, by means of the astronomical equation.”

After all, it is still not clear why such an absolute time, that is similar in nothing to what we can learn from our experience, should exist by itself as a thing in the real world. From where it comes the necessity to posit an absolute time independent of everything else? The reason is well explained by Enrico Bellone, and it’s mathematics:

“A differenza di Galilei, che utilizzava come sistema formale la teoria delle proporzioni euclidee tra grandezze omogenee, Newton possedeva i primi elementi del calcolo infinitesimale. Per Galilei, ragionare su un termine come ‘velocità’ era molto difficile, in quanto una velocità è un rapporto tra spazio e tempo. La difficoltà galileiana stava nell'impossibilità di pensare un rapporto tra grandezze non omogenee: spazi e tempi non sono affatto omogenei, e un rapporto tra spazi e tempi ha lo stesso senso di un rapporto tra fagioli e odori. Galilei era conseguentemente costretto a ragionare su rapporti tra velocità, e a esprimerli con un algoritmo che potrebbe avere una forma come questa:

$V1/V2 = (S1/S2) \cdot (T2/T1)$

Questo modo di pensare la velocità genera problemi che complicano la vita a ogni piè sospinto, […]. Newton, invece, ha in mano il concetto di funzione. Egli, pertanto, può pensare la posizione di un punto nello spazio, e può anche pensare il moto come *variazione di posizione*, in quanto la variazione di posizione è misurabile. Ma la variazione di posizione nello spazio coinvolge una variazione temporale. Se un punto passa da una posizione *A* a una posizione *B*, allora quel punto sta *prima* in *A* e *poi* finisce per stare in *B*. Che cos'è la differenza tra *prima* e *poi?* Si può rispondere in forma triviale: la differenza è una durata, un intervallo temporale. Newton non credette che la risposta fosse innocua, e ritenne, invece, che la domanda fosse terribile. Infatti: per descrivere il moto, so che devo misurare una variazione spaziale e che devo anche misurare una variazione temporale, ma so, soprattutto, che quando misuro una variazione temporale, non posso fare altro che misurare un movimento. Quale movimento? Il movimento osservabile in un manufatto che mi hanno insegnato a usare per valutare numericamente i tempi. Una clessidra, ad esempio. In una clessidra ci sono granelli di sabbia che si muovono. *E non c'è* *proprio nient'altro*. E non c'è nient'altro che moto anche se getto via la clessidra e osservo i moti ciclici della Luna." (Bellone, 1994)[31]

This inexorable relativity of the measurement of time was already present in Augustin and made clear by Giordano Bruno and Leibniz (all predecessor or contemporaneous of Newton) before being formalized in the theory of general relativity by Albert Einstein (see Giannetto, 2005).

Nevertheless, Newton solved the problem of the relativity of measurement of time(s) in a Platonic way. The need to specify the variable "t" in mathematical equation, in order to be able to describe 'motion' in function of 'time' (and not in function of another motion!) and define then the concept of *speed* and *acceleration*, was for Newton too impellent. According to Bellone (1994), Newton considered all the possible function describing mathematically all the possible motions in space, arbitrarily choose one of them hypothesized *ad hoc* its constant speed, and called it "Time". What is important for us is to understand that no metaphysical elucubrations, but mathematical necessity played the major role in the definition of the Newtonian absolute time. Among

[31] Galileo used the theory of Euclidean proportions between homogeneous magnitudes as a formal system. Newton, instead, possessed the first elements of the infinitesimal calculus. For Galileo, reasoning about a term as speed was very difficult, because a speed is a ratio between space and time. The difficulty is that for Galileo was impossible to think a ratio between non-homogeneous magnitudes; spaces and times are not homogeneous, and a ratio between spaces and times has the same sense as a ratio between beans and smells. Galileo was, consequently, constricted to reason on ratio between speeds, and express them with an algorithm that could have this form:

$$V1/V2 = (S1/S2) \cdot (T2/T1)$$

This way to think about speed creates several problems […]. Newton, instead, possess the concept of function. He can represent the position of a point in the space and can represent the motion as the variation of the position, because the variation of position is measurable. But the variation of position in space involves a temporal variation. If a point pass from a position A to a position B, that point stay in A *before* and stay in B *after*. What is the difference between *before* and *after*? It is possible to answer trivially: the difference is a duration, a temporal interval. Newton did not belief that the answer was harmless, and thought, instead, that the question was terrible. Indeed: to describe motion, I have to measure a spatial variation, and also a temporal variation, but, I know, also, that when I measure a temporal variation I cannot do anything else that measuring a movement. Which movement? The observable movement of a artefact that someone taught me to use to evaluate times numerically. An hourglass, for example. In a hourglass there are moving grains of sand, *and nothing else*. And there is nothing but motion even if I throw away the hourglass and I look to the cyclic motion of the moon."

others, Ernst Mach had suggested how, indeed, talking about an Absolute time, in metaphysics terms, it is potentially a loss of time:

"It is utterly beyond our power to measure the changes of things by time. Quite the contrary, time is an abstraction, at which we arrive by means of the changes of things; made because we are not restricted to any one definite measure, all being interconnected. A motion is termed uniform in which equal increments of space described correspond to equal increments of space described by some motion with which we form a comparison, as the rotation of the earth. A motion may, with respect to another motion, be uniform. But the question whether a motion is in itself uniform, is sensless. With just a little justice, also, may we speak of an 'absolute time' – of a time independent of change. This absolute time can be measured by comparison with no motion: it has therefore neither a practical nor a scientific value; and no one is justified in saying that he knows aught about it. It is a idle metaphysical conception." (Mach, 1919, pag. 224)

Nevertheless, the mathematical one, it is probably not the only reason that drove Newton to the conception of an absolute time (and space). The space doesn't allow us to take in consideration the important influence of theology and religious view on many Newtonian positions (See Giannetto, 2005 for an introduction), but we will consider the suggestions made by Vicario. According to him, Newton found that the absolute time was necessary to explain the persistence of the existence of the things (perseverantia existentiae rerum):

"Il ragionamento sarebbe press'a poco questo: a) il tempo è necessario perché le cose esistano: nessun oggetto può essere considerato reale se non ha una durata anche piccolissima; b) questo va bene se c'è un moto, un cambiamento, ad alta come a bassa velocità; c) ma che cosa succede se non c'è alcun moto? d) in assenza di moto o di cambiamento il tempo non esiste; e) ne consegue che oggetti reali che si fermino o che cessino nel loro cambiamento non esistano; f) ma non si può ammettere che una volta fermi o avendo cessato di cambiare, non esistano più; g) e allora creiamo un tempo speciale, assoluto, nel quale gli oggetti fermi o inalterabili continuano a esistere." (Vicario, 2004, p. 31)[32]

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"The reasoning is, more or less, like this: a) time is necessary for the existence of things: a object cannot be considered real if it doesn't have a duration, even very small; b) this is ok if there is a motion, a change, with high or low speed; c) but, what happens if there is no motion?

The last thing that we could ask, going back to one of the consideration exposed at the beginning of this paragraph, is why the absolute time, considered as a real 'object' or 'feature' of the world, has acquired so much popularity, especially among the psychologists. The argument proposed by Vicario is so simple that it's likely to be true. Color exists to the side of the observer, and in the physical side electromagnetic radiation exists; similarly, sounds exist for the observer and pressure waves exist in a physical perspective; on one side, flavours and smells exist, on the other chemical reactions; the sensation of time exists, then, on the other side, the physical world, something else should exist: the Newtonian time. What else?

This argument is referred especially to the sub-field of psychophysics, and in spite of its simplicity, lead to a dramatic conclusion. The psychophysics studies the relation between stimuli and responses, the relation between forms of energy or information with the observable part of physiological and mental states such as behavior, verbal production, physiological indices, etc. But, if absolute time "it is not a form of energy or information, but an abstract schema of relations between events [motion, changes]" (Vicario, 2004) the conclusion is that it is impossible to do a psychophysics of time.

## 2.6 Locke

John Locke, is traditionally considered the father of the English Empirism. As noticed by G.H. Mead, Locke was born in a period in which the Cartesianism was the philosophic orthodoxy "from the Pillars of Hercules to the Northern Sea, and from the Atlantic Ocean to the barbarism of Russia" (Mead, 1882). As like as Descartes, Locke's philosophic method starts with the doubt, proceeds with a positive analysis and with a sound faith in the power of human reason, and look with admiration to the rising natural

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D) without motion or change, time does not exist; e) that imply that real objects that stop or finish to change do not exist; f) but we cannot admit that once they are arrested, or once they have stopped to change, they don't exist anymore; g) therefore, we create a special time, absolute, in which static or inalterable objects continue to exist" (our translation) science[33]. Nevertheless, Locke opposed to the doctrine of the innate ideas of the French philosopher his well known concept of “tabula rasa”[34]. In this view, the human mind receives all its knowledge through experience, because at the time of birth the mind is a "Tabula Rasa" ready to receive any impression that may be made upon it. Locke's "Treatise on Human Understanding" is devoted to the deconstruction of the doctrine of Innate Ideas.

Famous is his statement “Nihil est in intellectu quod non prius in sensu”, and this should be true also for the ideas of *space* and *time*.

Very briefly, we could say that, according to Locke, such a thing like innate ideas do not exist. The mind is a blank page on which the experience can leave theirs impressions. Ideas are provided to the mind, from the experience, through *sensation*, or *reflection*. Through *sensation*, the experience conveys to the mind knowledge from the external sensible objects, providing ideas like yellow, cold, soft, bitter and all the others ‘sensible qualities’ of the external world; through *reflection*, the experience provide us knowledge about the operation of our own mind, in the form of ideas like perception, thinking, doubting, believing, willing, etc. *Sensation* and *reflection* provide the basic materials (simple ideas) upon which most of our more complex knowledge is constructed.

We can now anticipate that for Locke, the idea of space is a ‘simple idea’ derived from the senses, so it is object of sensation; the idea of time (in terms of simple ideas like *succession* and *duration*) is derived from the ‘train of ideas’ taking place in our mind, then it is object of reflection.

According to Locke, it is going back to these original sources of our knowledge that we can understand time and avoid the Augustinians “Si non roga, intelligo”. Locke writes:

“It is evident to any one who will but observe what passes in his own mind, that there is a train of ideas which constantly succeed one another in his understanding, as long as he is

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[33] “… in an age that produces such masters as the great Huygenius and the incomparable Mr Newton, with some others of that strain, it is ambition enough to be employed as an under-labourer in clearing the ground a little, and removing some of the rubbish that lies in the way to knowledge” (Locke, *Epistle to the reader*, quoted in Dennet, 2006)

[34] An Aristotelic term that Locke probably found reading the work of Pierre Gassendi (See Jaynes, 1985)

awake. Reflection on these appearances of several ideas one after another in our minds, is that which furnishes us with the idea of succession: and the distance between any parts of that succession, or between the appearance of any two ideas in our minds, is that we call duration" (Locke, 1689/1975, p. 165)

Our knowledge about duration and succession comes from inside, from the operation of our mind (or soul), and not from the happenings in the outside world. In this view, Locke can be numbered among those philosophers, who proposed a subjective origin of the temporal knowledge. Time, hence, it is not a property of the world and the objects, but it's projected over them by extension (from the mind):

"Indeed a man having, from reflecting on the succession and number of his own thoughts, got the notion or idea of duration, he can apply that notion to things which exist while he does not think" (Ibid. p. 166)

Nonetheless, our concept of duration and succession cannot be derived from the experience of an external, absolute time as suggested by Newton:

"… men derive their ideas of duration from their reflections on the train of the ideas they observe to succeed one another in their own understandings; without which observation they can have no notion of duration, whatever may happen in the world." (Ibid. p. 167)

According to Locke, given the simple ideas of duration and succession, 'Time' is duration set out by measures:

"Having thus got the idea of duration, the next thing natural for the mind to do, is to get some measure of this common duration, whereby it might judge of its different lengths, and consider the distinct order wherein several things exist; […] This consideration of duration, as set out by certain periods, and marked by certain measures or epochs, is that, I think, which most properly we call time." (Ibid. p. 171)

Locke is convinced that an exact measure of time is impossible, mostly because "no two different parts of succession can be put together to measure one another".[35] This intrinsic inaccuracy of temporal measures, that was noted by Augustine and was source of problems for Newton, it doesn't seems to be a problem for the British philosopher, to whom the idea of time is clear, even if time it is note liable to exact measure. Thus, by *reflection* upon the flux of ideas on our mind, and by *sensation* observing regular and, apparently, equidistant periods like the astronomical events, we can get the ideas of fixed temporal lengths as minutes, hours, days, years, etc. Moreover:

> "by being able to repeat those measures of time, or ideas of stated length of duration, in our minds, as often as we will, we can come to imagine duration, where nothing does really endure or exist; and thus we imagine to-morrow, next year, or seven years hence." (Ibid. p. 180)

The idea of infinite time, or eternity, is finally constructed repeating the idea of such a temporal interval (as a minute, a moment, a year), and continuing with this addiction without foresee an end.

The philosophical inquiry of John Locke is about human understanding, for this reason, once he has found the primary source of temporal knowledge in the simple ideas of *duration* and *succession*, the relativity or even impossibility of any measure of time, or the conditions for the existence of an external, absolute time is not a problem for him. He is interested in how our mind can built up representations, knowledge, that allow to a that are more and more complex temporal reasoning. In these terms, he's surely more close to the objectives of the modern psychology and cognitive sciences.

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[35] More specifically:
"We must, therefore, carefully distinguish between duration itself, and the measures we make use of to judge of its length. Duration, in itself, is to be considered as going on in one constant, equal, uniform course: but none of the measures of it which we make use of can be known to do so, nor can we be assured that their assigned parts or periods are equal in duration one to another; for two successive lengths of duration, however measured, can never be demonstrated to be equal. […]Since then no two portions of succession can be brought together, it is impossible ever certainly to know their equality. All that we can do for a measure of time is, to take such as have continual successive appearances at seemingly equidistant periods; of which seeming equality we have no other measure, but such as the train of our own ideas have lodged in our memories, with the concurrence of other probable reasons, to persuade us of their equality" (p. 175)

Among the reasons for which we put John Locke in our short list of philosophers of time, there is the fact that he explicitly reflects upon the relationship between the concept of space and time in our mind. The Chapter XV of the Book II of the *Essay* is titled "Of duration and expansion considered together". In this chapter Locke highlighted systematic analogies between time and space.

Both time and space (or, better, duration and expansion), for example, are conceived in limited experiences, but can be extended in our mind, and applied to infinite expansion or duration. They belong to all finite beings, since "where" and "when" are questions that can be asked about any sensible object, because the existence of each sensible object can be easily ascribed to a portion of duration and extension. Space and duration are continuous and un-differentiated, so that all the parts of extension are extension, and all the parts of duration are duration. Both duration and expansion are subject to quantification, and they can be conceived in terms of 'more' and 'less'. Time in general is to duration as place to expansion, so that it is possible to determine 'where' and 'when', in relation to fixed points of reference. Finally, both space and time are infinitely divisible, even though their parts are inseparable.

A couple of important differences, pointed out by Locke, concern the 3-dimensionality of spatial extension compared to the 1-dimensionality of duration; and the fact that duration has never two parts together, but always in succession, whereas space has never succession but his parts always exist together:

"Duration, and time which is a part of it, is the idea we have of perishing distance, of which no two parts exist together, but follow each other in succession; an expansion is the idea of lasting distance, all whose parts exist together, and are not capable of succession" (Ibid. p. 188)

To conclude, Locke writes:

"… expansion and duration do mutually embrace and comprehend each other; every part of space being in every part of duration, and every part of duration in every part of expansion. Such a combination of two distinct ideas is, I suppose, scarce to be found in all that great variety we do or can conceive, and may afford matter to further speculation." (Ibid. p. 188-189)

The idea that space and time are symmetrically interrelated and mutually dependent will be indeed matter of further speculation and experimentation in the second chapter of this thesis. For the moment it is enough to remark how the representation of time suggested by Locke, is clearly based on the spatial analogy explained above, for which time is conceived in terms of a quantifiable homogeneous extension, a succession of units of time.

## 2.7 Kant

"Before Kant, one might say, we were in time; now time is in us."

*Arthur Schopenhauer*

The Kantian position that describes time as an *a priori* condition to the experience is widely known in its general terms. Like for the previous philosopher that we analyzed, abstracting the argument that Kant use to describe time, and temporal experience, without considering the whole theoretical Kantian corpus, and limiting the analysis to only one of his writing (the *Critique of pure reason*) cannot be considered, to use an euphemism, a critical step in the history of philosophy. Nevertheless, even a superficial understanding of Kant's ideas about time can be useful for the sake of this thesis, in order to pursue the limited but important objective to be aware of the several epistemological position that can underline the study of time in a laboratory of psychology as well as during a field work in the middle of the Amazon forest. We can say, of course, that we are just studying 'time itself', but, in such a case, instead of being exempted to choose between fuzzy philosophical views, we will surprise ourselves using the philosophical view that the *common sense* provides us (without asking). In this view, we will use the Kantian theory of time in two ways: 1) if it's true that a new idea can be understood only considering the previous ideas from which it differentiated, then we will consider Kant's theory of time as a significant counterpoint (among others) to the Newtonian absolute time; 2) on the other hand, it will offer us the possibility to reflect over the terms “objective” and “subjective”, referred to the experience/existence of time; 3) further comment on the spatialization of temporal knowledge in the kantian analysis will be provided eventually.

Kant’s definition and description of the a priori concept of space and time are presented just at the beginning of the *Critique*, in the “Transcendental aesthetic”. He writes:

> “Time is not an empirical concept drawn from any experience. For simultaneousness or succession themselves would not come into perception, if the representation of time were not underlying a priori.” (Kant, 1781/1982, p. 20)

Already from these firsts lines we can see how the philosopher assumes a clear anti-realistic position, diametrically opposed to the hyper-realistic Newtonian ‘absolute time’. In fact, if we cannot drawn the concept of time from the experience, neither perceptual or intellectual, it means that time has to be super-imposed on the experience by the subject, and that subjects and objects are not already *in* time. According to Kant, not only time cannot exist by itself, but is the *condicio sine qua non* for having all the intuitions [perception, sensations]:

> “Time is a necessary presentation underlying all intuitions. One cannot, in respect of appearances generatim, suspend time itself, although one can very well take away the appearances out of time. Time, therefore is given a priori. In it alone all actuality of appearances is possible. Time is the general condition of their possibility” (*ibidem*, p. 21 )

Kant beliefs that we cannot conceive intuitions or appearances of the objects (the object itself, *noumeno*, it’s unknown by definition) without a temporal frame, but it is possible to conceive this temporal frame without appearances. Therefore time has to be a knowledge *a priori*, and not *a posteriori*. Taken by itself this is not a strong argument (see also Ricoeur, 1988), but considered the partial reading we are doing we will suspend our judgment about it. However, an opposite argument, as we have seen, was proposed from Aristotle according to which the experience/knowledge of change was at the basis of the experience of time, a point of view that characterize time as a derived concept, a knowledge acquired *a posteriori*, in Kantian terms. Kant's opinion on the implicative direction of the relation between 'time' and 'change' is peremptory:

> "… the concept of change, and, with it, the concept of motion (as change of locus) is possible only through and in the presentation of time. If this presentation were not an (inner) intuition a priori, no concept of any kind could make the possibility of change comprehensible, that is, the possibility of a conjunction of contradictorily opposed predicates in one and the same object (for example, the being in one locus and the not being, in the same locus, of the same thing). Only in time both contradictorily opposed determinations can be met with in one thing, namely, successively" (*ibidem*, p. 22)

But is it possible to conceive succession without experiencing any kind of internal or external change? Different people have different opinion about it (see for example Aristotle above), and this sort of ἀπορία give us some of the flavor of this thousands-year discussion.

The third argument that Kant gives in the *Transcendental Aesthetic*, to support the status of an *a priori* intuition of time is the following:

> "This necessity a priori is the basis of the possibility of apodictic propositions concerning the relations of time, or of axioms of time generatim: Time has only one dimension; different times are not simultaneous but successive (as different spaces are not successive but simultaneous). These basic propositions are valid as rules under which experiences generatim are possible, and they instruct us prior to experience, not through it." (*ibidem*, p. 21)

This argument finds his basis in David Hume's philosophy (whom Kant admitted to have interrupted his 'dogmatic slumber'). To the skeptical approach of Hume can be associated the claim that the concept of 'necessity' cannot be gained from experience.[36] If we hit a billiard ball with another billiard ball, the ball that was static starts moving, after the hit. We can do this experiment different time, and after some trial we can say that the steady ball will necessarily move after the hit with the other ball. But, in fact, the idea of 'necessity' cannot come from the only experience. The

[36] Actually, Hume, after having failed to find any other acceptable explanation will explain the concept of necessity in connection with the principle of habitus and, in general, with the past experience.

experience can provide us only with a limited number of cases; it never tells us what happens *in all cases*, and consequently does not yield necessary truth.

Since the characteristics of time (succession and unidimensionality) are apodictically true, so that are necessary in the light of our reason (in the sense that however you think at it, it cannot be other way), and this temporal characteristics are necessarily associated to any kind of experience, this necessary association can be possible only in regard to an *a priori* knowledge.[37] Because nothing, in the experience, can inform us about the *necessity* of an association (or cause). At least, this is how we've understood this Kantian argument.

As we promised, we are going to conclude with a reflection on the notion of 'subjectivity' and 'objectivity' of time. Kant writes:

> "If abstraction is made from the sensibility of our intuition (from the manner of presentation peculiar to us) and if one speaks of things generatim, time is no longer objective. But time is necessarily objective in respect of all appearances, thus all things that may occur to us in experience. The proposition: All things as appearances (object of sensible intuition) are in time, is a fundamental proposition that is objectively correct and has universality a priori.
>
> Accordingly, our assertions teach the empirical reality of time, that is, its objective reality in respect of all objects that may ever be given to our senses. But we deny time any claim to absolute reality, that is, irrespective of the form of our sensible intuition. This constitutes its transcendental ideality, which does not permit us to ascribe time to objects in themselves, whether as substance or as inherence, once abstraction is made from the subjective conditions of our sensible intuition." (*ibidem*, 23)

According to Kant time has an *empirical reality*, but not an *absolute reality*. Temporal representation (or better, *presentation*) of the events is subjective in the sense that take place in each subject, taken one by one, but is objective because the mental processes that underline it work in the same way between different subjects and, within the same subject in different moments (see Vicario, 2005, p. 32).

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[37] Ricoeur put it like this: "As we can represent only a unic space, of which the other spaces are part of it, similarly different times cannot be but successive; this axiom which gives the unidimensionality of time it is not a product of the experience, but it is presupposed to the experience" (Ricoeur, 1988, p. 72, our translation).

Kantian time is an empty time. It is homogeneous in relation to all the intuitions because all the intuitions can be 'placed' in time, with a duration, and a succession. Time, for Kant is a schema of relations, which is separable from the events that contains. Time, as a priori condition of knowledge, is neither qualitative nor quantitative, being 'quality' and 'quantity' different 'forms of understanding'. The kantian time, as homogeneous extention (in one dimension) can be ascribed, we think, to the spatialized conceptions of it, which we have seen repeted in many philosophical views. The *extensive* nature of Kantian time appear clear in these parts of the *Critique*, drawn to our attention by Ferraris (2009):

"In an extensive quantity, the presentation of the parts makes possible the presentation of the whole (and therefore necessarily precedes it). All appearances as mere intuitions in space or time are therefore already intuited as aggregates (multiple of pre-given parts), which is not the case with all kinds of quanta but only those which are presented and apprehended by us as extensive ones" (*ibid.* p. 69)

Even if Kant internalized the conception of time, rebutting the idea of an *Absolute Time* independent of any aesthetic judgment, his *a-priori* representation of time is based on the representation of space. Kant himself seems to be aware of this when he writes: "We cannot represent time, which is not an object of external intuition, in any other way than under the image of a line, which we draw in thought". (*Critique of pure reason*, B, 156)[38] In other words, our experience of time (the only thing we might know about time) is based on our spatial experience.

According to the interpretation of Maurizio Ferraris:

"nella trattazione dello spazio e del tempo, Kant descrive insieme delle proprietà che si trovano apriori nell'anima e delle condizioni di possibilità della conoscenza di qualcosa che è esterno rispetto all'anima. Il massimo risultato, almeno a questo livello, è di avere assicurato un terreno comune per l'ideale e il reale (attraverso la congruenza tra lo spazio geometrico e lo spazio empirico), e quindi di aver dimostrato come l'interno e l'esterno non siamo esteriori

[38] This extract, quoted in Ferrarsi (2009), refers to the second editinon 'B', of 1787. Previous quotations refers to the first editino (1781)

l'uno all'altro, ma anzi necessariamente comunichino, attraverso la naturale tendenza del tempo a raffigurarsi come spazio."[39] (Ferraris, course notes, 2009)

## 2.8 Bergson

"*all the relations which cannot be translated into simultaneity, i.e. into space, are scientifically unknowable*."

Henry Bergson

The analysis of the philosophy of Henry Bergson, especially how it is presented in his first book *Time and free will* (1889/1910), will deserve a long coverage. In fact, the ideas of Bergson, for what we could understand, are somehow precursors of the recent developments in cognitive sciences, which constitute the debated topic of this thesis. The *spatialization* of time that, as we tried to show, implicitly accompany the philosophy of the classic Greece and most of the modern philosophical thinking, is made explicit and well analyzed in Bergson. To the widespread representation of time as an homogenous extension, that Bergson characterized as surreptitiously based on the former idea of space, the French philosopher opposed his concept of *duration* which is unextended and heterogeneous, as well as the pure and immediate temporal experience. The analysis of Bergson's philosophy will help us to disentangle some of the processes according to which we come to represent time in terms of spatial extension both in the philosophical or scientific thought and at level of the human mind.

The first chapter of *time and free will*, (which was actually the last that has been written) is a critical review of the psychophysical approach to the measure and representation of internal sensations and mental states. At that time, as well as nowadays, many psychophysicists supported a positivistic approach to the study of the mind for which the mental processes, even if complex, are still reducible to scientifical explanations and descriptions of the same order of the physical processes. The analysis

[39] "Talking about space and time, Kant describes together properties that are a-priori in the soul and conditions of possibilities of the knowledge of something that is external in respect to the soul. The maximum result, at this level, is to have provide a common ground for the ideal ad the real (by mean of the congruity between the geometrical space and the empirical space), demonstrating therefore how the internal and the external are not external one another, but instead, necessarily communicate through the natural tendency of time to depict itself as space" (our translation)

of the intensity of sensations, emotions and perceptions, compared to the variation of the intensities in the physical world (weight, light, loudness, etc.), the kind of relations to which referred the formulation of the first psychophysical laws (Fechner, 1860), appeared to Bergson the ideal ground upon which engaging in the falsification of this positivistic approach.

According to Bergson, it doesn't make sense to speak about quantity in rapport to sensations, emotions or mental states. More specifically, it does not make sense to talk in terms of 'more' and 'less' in the domain of not-extended things. In language we use spatial expressions (metaphors) to talk about mental facts and unextended objects because we require to establish between our ideas the same precise distinctions that we can establish between extended objects in space. So that people can be more or less sad or more or less happy, and nobody is surprised if we say that a sensation or an effort can be greater than another; but these expressions are the product of an intellectual process of spatialization that reveal itself to be problematic:

> "if we grant that one sensation can be stronger than another, and that this inequality is inherent in the sensations themselves, independently of all association of ideas, of all more or less conscious consideration of number and space, it is natural to ask by how much the first sensation exceeds the second, and to set up a quantitative relation between their intensities" (Bergson, 1911, p. 71)

In psychophysics the psychological, internal and unextended intensities are treated and measured like magnitudes, but, as we could see for the measure of space and time, any measurement of magnitude requires superposition, or a comparison with a unit of measurement that is homogeneous to the magnitude and contained in it, like a centimeter in a meter, or a gram in a kilo. But, the intensities of our sensations are not superimposable objects:

> "For it will then be necessary to explain why one sensation is said to be more intense than another, and how the conceptions of greater and smaller can be applied to things which, it has just been acknowledged, do not admit among themselves of the relations of container to contained." (ibid. p.71)

Bergson suggested that sensations more or less intense, therefore measurable, don't exist. The difference between them is qualitative and not quantitative. There are just different sensations and not degrees of the same sensation. According to Bergson the quantitative comparison always imply a container/contained relationship, adequate to explain relation between physic magnitudes and erroneously considered adequate to describe the intensity of internal sensations. This error is the result of a process of "hypostatization", in which a multitude of different processes are put into the form of a single growing, extensively changing, state.

To summarize, subjective phenomena like sensations are in themselves pure quality, on the other hand, their causes, situated in space, are quantifiable. In so far a qualitative state become the sign of a quantitative material cause, we can suspect, or infer, a quantitative nature to the sign itself, calling it *intensity*. Bergson writes:

> "If magnitude, outside you, is never intensive, intensity, within you, is never magnitude." (ibid. p. 225)

The critics to the psychophysical methods, although important, are not central for aim of this thesis. Nevertheless, the spatial metaphor at the basis of the confusion between what is extensive and intensive, or quality and quantity, will become more clear considering the problem of *duration*.

Bergson approaches the problem of duration starting from the analysis of what we call *number*. According to Bergson a number is a collection of units and, therefore, a synthesis of the one and the many.

> "Every number is one, since it is brought before the mind by a simple intuition and is given a name; but the unity which attaches to it is that of a sum, it covers a multiplicity of parts which can be considered separately."

The philosopher asks if the idea of number imply the representation of something else as well. The idea of number is a collection of units in which each unit is identical to the others, or at least we should assume that they are identical when we count. For example, in counting the sheep of a flock in the number of 50, we left aside all the differences that exist between the single sheep, considering only what they have in common. In that way the sheep become the homogeneous unit of a quantity. On the other hand, the units of a total have to be somehow *distinct* from one another, otherwise, they will form a single indistinguishable unit. For example, even if we imagine that all the sheep are identical, they should differ at least from the position they occupy in space, otherwise we won't have any flock! With a last effort of imagination we could forget about the actual sheep and consider only the image of them. We have about two way to represent the idea of flock: either we put the units side by side in an ideal space, or we repeat fifty time in succession the image of a single units. The last condition, is supposed to happen in time. The important contribution made by Bergson consists exactly to demonstrate that even in the second condition we are placing the sheep in a ideal space. A part from the sheep, the argument is serious and complex.

"For if we picture to ourselves each of the sheep in the flock in succession and separately, we shall never have to do with more than a single sheep. In order that the number should go on increasing in proportion as we advance, we must retain the successive images and set them alongside each of the new units which we picture to ourselves: now, it is in space that such a juxtaposition takes place and not in pure duration. In fact, it will be easily granted that counting material objects means thinking all these objects together, thereby leaving them in space." (ibid. p. 77)

This is true also for 'abstract' numbers: if we count until 50, when we arrive at the end of the count we'll have the impression of having built up the number in duration, and just in duration. Of course, we were not actually counting single points in space, but, according to Bergson, we counted the moments of duration "by means of points in space" (ibid. p. 77). When we picture numbers to ourselves, and not symbols or words that stand for the numbers, we always have to do with an extended collection that take place in an ideal space.

Bergson writes:

"For though we reach a sum by taking into account a succession of different terms, yet it is necessary that each of these terms should remain when we pass to the following, and should wait, so to speak, to be added to the others: how could it wait, if it were nothing but an instant of duration? And where could it wait if we did not localize it in space? We involuntarily fix at a point in space each of the moments which we count, and it is only on this condition that the abstract units come to form a sum." (ibid. p. 79)

The conclusion of Bergson, here summarized, is that if all addition imply a multiplicity of parts simultaneously perceived, we must always have thought about numbers as juxtaposition in space.

Whether or not it is always the case, or it has ever been the case, this analysis of the representation on numbers conduces Bergson to notice that there are at least two different kind of *counting*. We can count physical objects, that we can see and touch, and count them in the same medium in which we can observe them, namely *space*. On the other hand, we can count psychic states, mental events or sensations, caused or not by external events perceived through a mean different than sight of touch. In the last case, we can count them only by some process of symbolical representation. We can think for example to a succession of sounds, like a succession of 'gong' of a bell. According to Bergson:

> "The sounds of the bell certainly reach me one after the other; but one of two alternatives must be true. Either I retain each of these successive sensations in order to combine it with the others and form a group which reminds me of an air or rhythm which I know: in that case I do not count the sounds, I limit myself to gathering, so to speak, the qualitative impression produced by the whole series.
>
> Or else I intend explicitly to count them, and then I shall have to separate them, and this separation must take place within some homogeneous medium in which the sounds, stripped of their qualities, and in a manner emptied, leave traces of their presence which are absolutely alike. The question now is, whether this medium is time or space." (ibid. p. 86)

A moment of time cannot persist in order to be added to the others, moreover, if the sounds are separated, and are forming a total of discrete units, also the intervals between them must remain. But how can they remain if they are pure duration? The answer of the philosopher is that the sounds should be counted in space:

"Our final conclusion, therefore, is that there are two kinds of multiplicity : material objects, to which the conception of number is immediately applicable, and the multiplicity of states of consciousness, which cannot be regarded as numerical without the help of some symbolical representation, in which a necessary element is space." (ibid. p. 87)

As the intensity of psychic states, that is inherently qualitative, is represented quantitatively as progressively growing in space, *time* is generally represented as a homogeneous medium in which our conscious states are ranged alongside one another as in space, so as to form a discrete multiplicity.

We are going to leave aside, for the moment, the process according to which human beings built up the representation of an homogeneous space, or the "special faculty of perceiving or conceiving a space without quality" (ibid. p. 97), that "enables us to use clean-cut distinctions, to count, to abstract, and perhaps also to speak." (ibid. p. 97). But it should be clear how, according to Bergson, this space without quality, this extension infinitely divisible in equal parts, that stands at the basis of our concept of number, shapes our representation of the world in a way that is only human.

Rather we are going to concentrate our efforts to understand how time can be represented as a homogeneous extension, and how this is a more or less essential part of human nature. It is well known that Bergson has distinguished what he called the *real duration*, to what he called *time*. With the latter being the spatialized symbolical representation of the former. According to Bergson:

"Pure duration is the form which the succession of our conscious states assumes when our ego lets itself live, when it refrains from separating its present state from its former states." (ibid. p. 100)

But in our reflective cosciousness time is symbolically represented in terms of space:

"For if time, as the reflective consciousness represents it, is a medium in which our conscious states form a discrete series so as to admit of being counted, and if on the other hand our conception of number ends in spreading out in space everything which can be directly counted, it is to be presumed that time, understood in the sense of a medium in which we make distinctions and count, is nothing but space." (ibid. p. 91)

We experience physical objects to be exterior to one another, and to ourselves. Precise boundaries can be traced between them in space, and the intervals between things are filled by empty space as a homogeneous medium. This reciprocal exteriority cannot be taken for granted if we consider matter at a sub-atomical level, but that's how it appears, without effort, to our senses, to the sight, to the touch. On the other hand, we do not experience conscious mental states as exterior to one another, if not after an effort of abstraction. We cannot trace distinct border between our impressions if not putting them in juxtaposition in a ideal homogeneous mean, mapping them, in some cases, from the distinct positions occupied in space by the objects that are the cause of these impressions. Again, this confusion come from the attempt to treat as extended what is unextended, namely the conscious states which, according to Bergson, compenetrate each other and form a whole that we can appreciate without attempting to separate the previous states from the former states. Nothing but this heterogeneous succession of conscious states is the *real duration*. We can remark how the bergsonian duration is similar to the 'distentio animi' of Augustine, which cannot be divided in past, present and future, but can be just conceived as continuous heterogeneous change, a process from which no point, instant or interval can be extracted without break the process itself, or without spatializing it. It is also important to remark that succession it is not synonymous of order. The position of Bergson is radical. If Aristotle define time as "the number of change", expression in which 'number' should be considered as 'order' and not as 'magnitude' (Coope, 2005; Giannetto, 1998), according to Bergson, ordering events according to the 'before' and the 'after' is already a trademark of spatialization. We cannot introduce order among terms without first distinguishing them and then comparing the places which they occupy in space. We have an order in (temporal) succession only when succession is converted in simultaneity and is projected into space. To give an example that can help to conceptualize this 'succession without order' we can think to those experiments in which two flashes, or sounds, are presented to the observer in a very rapid succession. At a certain threshold, the observer say that he has seen two stimuli, and that they were not simultaneous but in succession, but it cannot say in which order the two stimuli were presented.

According to Bergson, to experience the real duration, the subject (or the *ego*):

> "… needs not be entirely absorbed in the passing sensation or idea ; for then, on the contrary, it would no longer endure. Nor need it forget its former states: it is enough that, in recalling these states, it does not set them alongside its actual state as one point alongside another, but forms both the past and the present states into an organic whole, as happens when we recall the notes of a tune, melting, so to speak, into one another […] We can thus conceive of succession without distinction, and think of it as a mutual penetration, an interconnexion and organization of elements, each one of which represents the whole, and cannot be distinguished or isolated from it except by abstract thought." (ibid. p. 100)

The phenomenological description of the real duration provided by Bergson is complex and difficult to picture for a reflective consciousness, which we are probably using to understand these lines, and which is organized in spatial terms. In fact, what is interesting for us is that, according to the philosopher, we usually do not think about time as the 'real duration', but we think about it as a spatialized, measurable and homogeneous mean in which the event are distinguishable and succeed each other according to an order and a direction. Therefore we can ask why it is so difficult to think in terms of real duration? And what we are actually doing when we measure or represent time as a space?

According to Bergson, if we find difficult to think about duration in non *spatialized* terms, it is because "we do not endure alone, external objects, it seems, endure as we do, and time, regarded from this point of view, has every appearance of a homogeneous medium" (ibid. p. 107). The time in the calculations of the astronomers of the physicists, or the time that stand at the basis of the calculation of velocity of different things, strongly seems to be measurable. The question is simple as well as terrible: if duration by itself cannot be measured, what is that is measured by the oscillation of the pendulum?

According to Bergson, through the oscillations of the pendulum we are not measuring durations, but we are counting simultaneities:

“Outside of me, in space, there is never more than a single position of […] the pendulum, for nothing is left of the past positions. Within myself a process of organization or interpenetration of conscious states is going on, which constitutes true duration. It is because I endure in this way that I picture to myself what I call the past oscillations of the pendulum at the same time as I perceive the present oscillation. Now, let us withdraw for a moment the ego which thinks these so-called successive oscillations: there will never be more than a single oscillation, and indeed only a single position, of the pendulum, and hence no duration. Withdraw, on the other hand, the pendulum and its oscillations; there will no longer be anything but the heterogeneous duration of the ego, without moments external to one another, without relation to number. Thus, within our ego, there is succession without mutual externality; outside the ego, in pure space, mutual externality without succession: mutual externality, since the present oscillation is radically distinct from the previous oscillation, which no longer exists; but no succession, since succession exists solely for a conscious spectator who keeps the past in mind and sets the two oscillations or their symbols side by side in an auxiliary space. Now, between this succession without externality and this externality without succession, a kind of exchange takes place, […] As the successive phases of our conscious life, although interpenetrating, correspond individually to an oscillation of the pendulum which occurs at the same time, and as, moreover, these oscillations are sharply distinguished from one another, we get into the habit of setting up the same distinction between the successive moments of our conscious life the oscillations of the pendulum break it up, so to speak, into parts external to one another: hence the mistaken idea of a homogeneous inner duration, similar to space, the moments of which are identical and follow, with out penetrating, one another. But, on the other hand, the oscillations of the pendulum, which are distinct only because one has disappeared when the other appears on the scene, profit, as it were, from the influence which they have thus exercised over our conscious life. Owing to the fact that our consciousness has organized them as a whole in memory, they are first preserved and afterwards disposed in a series: in a word, we create for them a fourth dimension of space, which we call homogeneous time, and which enables the movement of the pendulum, although taking place at one spot, to be continually set in juxtaposition to itself.” (ibid. p. 108)

According to Bergson, time as we usually conceive it, is a product of the imagination, what really exists is succession without externalization inside us, and externalization without succession outside us. There is a real space, without duration, in which the phenomena appear and disappear simultaneously with our states of consciousness; and there is a real duration, in which heterogeneous moment permeate one another. In each moment, however, a state of consciousness can be brought into relation with a state of the external world which is contemporaneous with it. The moment correspondent to that state of consciousness, can be separated from the other moments in consequence of this very process.

> "The comparison of these two realities gives rise to a symbolical representation of duration, derived from space. Duration thus assumes the illusory form of a homogeneous medium, and the connecting link between these two terms, space and duration, is simultaneity, which might be defined as the intersection of time and space" (ibid. p. 110)

A similar analysis can be applied to motion. We can assert that motion take place in space, and certainly the different position of a body during motion correspond to a certain point in space. But motion is a progression, and the process for which the body passes from a position to the other is a duration, and this process exist only for a conscious mind.

Bergson suggested that there are two elements to be distinguished in motion, the space traversed and the act by which we traverse it, the successive positions and the synthesis of these positions. A synthesis that is qualitative and not quantitative, that is like a phrase in a melody. If we attribute to the motion the divisibility of a space, forgetting that it is possible to divide an *object*, but not an *act*, we give rise to the paradoxes of the Eleatics for which Achille will never reach the tortoise.

To measure the velocity of a movement is simply to ascertain a simultaneity, and introducing this velocity on other calculation is a good way to anticipate a simultaneity. But, admonishs Bergson, mathematics goes "beyond its province when it claims to reconstruct what takes place in the interval between two simultaneities" (ibid. p. 115). For these reasons science cannot deal with time and motion without first exclude the qualitative elements of both, namely *duration* and *mobility*.

> "Outside ourselves we should find only space, and consequently nothing but simultaneities, of which we could not even say that they are objectively successive, since succession can only be thought through comparing the present with the past. That the interval of duration itself cannot be taken into account by science is proved by the fact that, if all the

motions of the universe took place twice or thrice as quickly, there would be nothing to alter either in our formulae or in the figures which are to be found in them." (ibid. p. 116)

This last simple but significant argument does nothing but reasserting what was already clear for Augustine and Giordano Bruno, namely that the only thing we are able to measure is *space*. We count simultaneities and we measure spatial magnitudes, and it is from the result of these activities that we claim to measure duration and, by putting them in relation, velocity. Therefore, not only each measure of time is always a relation between events, like two moving/changing objects, or one object in quiet and one in movement, but it is not even the change, or the movement that we are measuring, but a succession of simultaneities. What happens between two simultaneities is impossible to measure, because is impossible to divide like a space. An act like hand clapping, pendulum oscillation or equinox precession, is in itself unique and indivisible, and pertains to the domain of quality, and not quantity. For these reason there are not two kind movements that are homogeneous, and the measure of time is always relative to the system of reference: the steps of Achille are qualitatively different of the steps of the tortoise, therefore Achille will probably win the race. The idea of a spatialized, homogenous and divisible temporal extension works very well until we take in consideration the simultaneities that are at the extremities of a temporal interval, but when we ask ourselves what happens during the temporal interval, when we approach the process of change instead of the results of the process (actively abstracted to the process itself), the conceptual, ontological and epistemological gaps left by considering duration what is only the shadow of space give rise to the Augustine's "I don't know" and the Zeno's paradoxes.

Bergson blames Kant who consider time as an homogeneous medium:

"He did not notice that real duration is made up of moment inside one another, and when it seems to assume the form of a homogeneous whole it is because it gets expressed in space. […]He thought that consciousness was incapable of perceiving psychic states otherwise than by juxtaposition, forgetting that a medium in which these states are set side by side and distinguished from one another is of course space, and not duration" (ibid. p. 232)

The reduction of time to space, implicit in most of the occidental philosophical discussion on the argument, becomes explicit in the writings of Bergson.

Like Augustine, Bergson denies the reduction of time to a homogeneous spatial extension that was somehow at the basis to the cyclic conception of time of the Greek ancient world. As the psychic (Giannetto, 1998) extension to which refer Augustine, the *distentio animi*, the Bergsonian real duration is a-topon, non-spatial, it is qualitative and 'intesive'. Time, as a process cannot be measured directly, because it is not an additive magnitude: its parts do not subsist together in a sum, but they 'flow'. A point of view that according Giannetto (1998) we can find also in the modern physic, for which time as a process it is not a extensive magnitude, but an intensive quality. Moreover, not only time is reduced to space when we face the problem of it's measure in the philosophic or scientific reflections, but we think about time in terms of space in our everyday experience of 'temporal' phenomena. According to Bergson, in our reflective consciousness, **time is space**. More recently, this idea has been somehow revived in what have been called the second generation of cognitive sciences, and it is the idea at the basis of this thesis. Nevertheless, this idea, as we will see in the next chapter, it has been ignored by the mainstream of the psychological studies, which took a different route.

# 3. The experience of time in psychology and cognitive science

The study of time from a psychological point of view began in the second half of the XIX century, relatively late considering the long story the problem of time has in the occidental philosophy. Block and Zakay (2001) especially blame Kant and some of the neo-kantian philosopher for this delay. They claim that the neo-kantian main stream considered time as an *a priori* dimension of human experience, an innate and transcendental knowledge impossible to study scientifically. We have already discussed (see 2.7) whether or not this interpretation of the Kantian thought is correct, but it is probably true that the popular idea of the transcendental nature of time has discouraged most of the psychological investigation on this topic.

We can get along the historical reports given by Block (Block, 1990; Block & Zakay, 2001) and Michon (Michon, 1988; Michon & Jackson, 1985) and consider the 1890 the *annus mirabilis* for the psychology of time. Indeed, it is in the 1890 that William James published his *Principle of psychology*, which contained a chapter on "The perception of time" that will have a strong influence in the field. In the same year, the French psychologist Guyau (1890/1988) published his book *Genèse de l'idée de temps*, concerning the development of the temporal concepts in the child. One year before, the French philosopher Henry Bergson (1989) published his doctoral thesis, *Essay sur le données données immediates de la conscience*, considered a milestone for the philosophy and psychology of time. Finally, in 1891 The American psychologist Herbert Nichols published his doctoral thesis, *The psychology of time*, that was the first extensive review of the experimental works on the topic. The important role of the French scholars in the psychology of time will be confirmed a few years later with the critical contribution by Janet (1928).

Nevertheless, even before 1890, important studies on the temporal experience has been done, especially in psychophysics. The following review will focus on the experience of duration and the studies that have approached in different ways this important aspect of psychological time. Many psychological model aiming to explain which are the biological or cognitive mechanism that underlie the experience of duration have been proposed through the times, we will consider those we think are the most representative. Moreover, the fact that the 2$^{nd}$ and the 4$^{th}$ part of this thesis are concerning the experience of duration and its representation in language and thought, should explain the peculiar focus of this review. Nevertheless, other aspects of time (i.e succession and simultaneity) will be investigated as well, in this chapter and in the next one.

## 3.1 The first steps: the biological clock and the 'time sense' approach.

From the half of the XIX century, we assist to a new way to study temporal experience, the empirical study about the precision of which humans perceive time. The first experimentalists investigated the classical problems of psychophysics in relation to temporal experience: does time perception respect Weber law?[40] Are there constant errors in the perception of time? What is the influence of the content of the temporal intervals on the perceived duration? Which is the shortest interval perceived in each of the separate senses?

At this time the study of the temporal experience moved into the laboratories, and the experiments performed by the subjects were mostly task of production, reproduction or comparison of temporal intervals or sequences of beats. Just for the record, the earliest report of an experimental observation in the psychological study of time, that Nichols (1891) were able to find, came from the Scotch philosopher Thomas Reid, who wrote the following:

> "I have found by some experiments that a man may beat seconds for one minute without varying above one second in the whole sixty; and I doubt not but by long practice he might do it still more accurately. From this I think it follows that the sixtieth part of a second of time is discernible by the human mind." (Quoted in Nichols, 1891, p.61)

Similar studies have followed. For example Mach (1866), reported that the Weber law it's not valid for temporal experience, so that the sensibility was negatively correlated to the length of the temporal intervals and varied daily; Vierordt (1868),

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[40] The Weber law, is a psychological law that quantify the perception of change in a given stimulus. The law states that the change in a stimulus that will be just noticeable is a constant ratio of the original stimulus. (See 3.4.2 for the application of the Weber law to time)

reported that across many conditions the relatively short intervals were lengthened by judgment and the relatively long intervals were shortened; Koellert (1882) confirmed Vierordt results using the method of the just noticeable difference; Ejner (1989) found that distraction of attention by the metronome, and performing arithmetical problems during the temporal reproduction tasks, caused decrease of sensibility for long intervals and shortening of judgments, the latter especially for short intervals; etc.[41]

In reintroducing the notion of 'specious present' (proposed at first by E.R. Clay (1882)) William James, in his *Principles of Psychology*, reviewed the work of those experimentalists who investigated what is the temporal threshold that marks the difference between symulataneity and succession in human perception. According James, what we can designate with the word 'now', our experience of the *present*, it is not punctate, but rather includes a small but extended interval of time. This interval is called the specious present, and what happens in the specious present appear to the consciousness as all-present-at-once. James roughly quantified the specious present as "varying from a few seconds to probably not more than a minute" (James, 1890/2007, p. 642). Very early, experimental psychologists have established empirically that perceived simultaneity does not correspond to physical simultaneity. Two successive signals presented in a very short time are often perceived as simultaneous, as happening in the same present moment. Nevertheless, if this effect is quite easy to induce, the attempt to discriminate the exact temporal threshold under which two successive events are perceived as simultaneous has revealed itself to be quite problematic. Many experiments have been done investigating this topic (Mach, 1865; Exner, 1875; Wundt, 1902; Hirsh, 1959, Hirsh & Fraisse, 1964; just to quote some of them) but the only generalizable outcome is that authors have in general given up to establish any stable threshold both within and between subjects (Fraisse, 1984; Vicario, 2005). Many factors are responsible for this variability, like the sensory modality in which the stimuli are presented (visual, auditory, tactil), the level of training of the subjects, the methodology used (monoaural, binaural, monocular, binocular, etc.), the type of stimuli (shapes, lights, string of letters), etc. (See Fraisse, 1984, for an extensive review). Considering

[41] All these studies are reported in Nichols, 1891

all this variability, the threshold[42] can vary between 10 to 400 ms, and the value it is not generalizable. Moreover, we should say that, as already showed by Wundt (1902) and remarked by Vicario (2005), not only two successive events can be perceived as simultaneous, but sometimes, two simultaneous events can be perceived as successive, and other times the order of two event can be inverted in our experience. These remarkable effects should prevent us to treat the phenomenological time as the more or less accurate reflex of the physical time, and they will be considered more deeply in the section 4.1 of this thesis.

Beside succession and simultaneity, two other aspects of psychological time that have been extensively investigated are temporal orientation and the experience of duration. Studies in temporal orientation are usually performed across relatively long temporal periods. Fraisse (1957) described experiment in which subjects were isolated for some days in a room with artificial light and were asked to estimate what time it was in different moments of their captivity. At the end of relatively short periods of 2-4 days they were surprisingly good to estimate the correct time with an error between 20 and 40 minutes, but during the experiment the error was increased since 4-5 hours. These results were probably due to the fact that temporal orientation was based on the estimation of the awakening time, a measure based on relatively stable biological rhythms. In fact when the subject were staying in the dark for all the duration of the experiment the estimation was less accurate, because the real sleeping time were augmented even though the subjects thought they were sleeping like usual. Interesting studies on temporal orientation has been done investigating the phenomenon of spontaneous awakening. Probably everyone of us know someone who claims to be able to wake up at any established time without any kind of alarm. This phenomenon has been largely study and revealed itself to be more than a legend (with a high variability between subjects). For example, Omwake and Loranz (1933) on the basis of a questionnaire selected ten students that claimed to be able, with a total certainty, to wake up at any hour they established the night before, and ten students who claimed not to be able at all to do so. Over 14 nights in which they were asked to wake up at

[42] For the sake of clarity, we should not to confuse this threshold, with James' specious present. In certain conditions the specious present can be much longer than that, like when different notes of a bar of a song seem to the listener to be contained in the present. These thresholds can be considered as a psychological, or even physiological, limit of the specious present, a limit under which is (theoretically) impossible to perceive two events as non simultaneous.

different times between 0:30 and 6:15, for the first group the awakening was possible on the 49% of the cases, for the second group just the 5% (with an error less than 30 min). Others studies confirmed these results (See Fraisse, 1957, pp.48-53 for a review), and, to our knowledge, the biological or psychological mechanism that allow this accuracy remain unknown.

The experience of duration has been largely studied in countless experiments. Psychologist has been interested on the sensorial features and the external or internal (non-temporal) factors that can influence the perception of duration. Concerning the sensorial limits and modality, for example, has been largely attested that auditory stimuli are usually perceived to be longer than visual ones (i.e. Behar & Bevan, 1961; Fraisse, 1984), that empty temporal intervals, auditorily presented, are usually perceived to last less that filled temporal intervals (i.e. Goldstone & Goldfarb 1963), or that a divided temporal intervals are perceived to be longer than continuous ones (Munsterberg 1889; Israeli, 1930; but see Adams 1977 for the effect of context that can decrease this illusion). Concerning the influence of non-temporal factors, we know that more intense sounds and lights are judged longer than less intense auditory and visual durations, and this effect is greater for vision (i.e. Triplett, 1931; Goldstone et al. 1978), and that also spatial distances can influence temporal estimation (Cohen, Hansel & Sylvester, 1953).

Many other studies, as we have already seen at the beginning of this paragraph, investigated the accuracy of duration estimations across different conditions (sensory modality, magnitude, methodology, etc.) and in different populations (i.e. schizophrenics, see Fraisse, 1957).

One of the objectives of these studies was to collect a large amount of empirical observation in order to establish some general characteristic of the experience of duration. One of the most diffused approaches, largely shared by the psychological 'common sense', has consisted in treating the temporal experience as a particular case of sensory perception. This view is, more or less explicitly, based on the epistemological assumption that a 'real' time exists in the 'real' world, independently of ourselves, like the absolute time in the Newtonian physics. If time exist as external process, that means that we can learn it, that we can know it as we know others concrete features of the world through the use of our senses. The idea to approach the experience of time as we have a special 'time sense' has been around from a long time but increased his popularity during the behaviorism: the necessity to be 'objective' and to clean-up psychological theories from what was considered 'mentalistic' made the 'time sense' approach easier to follow.

"If time was considered a 'sense' than it could at least been studied somewhat objectively, at least as objectively as vision" (Ornstein, 1969, p. 17)

Therefore, many experimental psychologists aimed to establish how accurate we estimate time and in which conditions, and the early attempts to determine psychophysical regularities, like the Weber law, for time 'perception' as it is for others kinds of perceptual domains (weight, distance, loudness), have been often guided by the 'time sense' epistemological principle.[43] The accuracy of time estimation was established with respect to the clock, which represents the real time that we can perceive accurately or not.

Particularly important, in this sense, are the studies on the *indifference interval*. Across different experiments (Fraisse, 1963; Woodrow 1934; and see Ornstein 1969 pp. 26-28 for a review) it has been found that below a certain temporal interval subjects over-estimate the duration of the interval, compared to the clock. Likely, over a certain interval subjects under-estimate it. There is, therefore, an interval for which the estimation results to be 'correct', compared to the clock. This interval is called the *indifference interval*.

Classically the indifference interval is reported to be circa 0.7 seconds, but as Ornstein pointed out, this value has been confirmed just in few of the many studies that has been done on duration accuracy,[44] and considering most of them the indifference value can vary form 0.5 to 3.5 seconds.

Like for the simultaneity/succession threshold, the only possible outcome is that "there is not such a thing as the indifference interval, unless this interval be defined

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[43] We can call it a principle, instead of a theory or a model, because in many works it is left implicit, or briefly developed, as often happens with theories that are close to the common sense representations.

[44] Some examples: Horing, 1.5 sec.; Kellert, 3.25 sec; Husler, 1.8 sec; Treisman, 3.0 sec; (See Ornstein, 1969, p. 26-27)

statistically in terms of some sort of average or most probable outcome" (Woodroow, 1934).

In spite of this large variability, many authors (See Woodrow, 1951 for a review) have associated the indifference interval with a sort of 'basic unit' upon which the human mind bases the evaluations of temporal extensions. Indeed, the physical time is measured on the basis of the repetition of relatively stable movements, like the hands of a clock or the oscillations of a pendulum. Similarly, our perception of time could be based on a temporal organ that works more or less like a clock, an internal biological clock which produces regular movements upon which time could be measured. In this view, the discovery of a temporal interval that can be estimated with a relatively accuracy compared to others temporal intervals can be see as an evidence for the existence of such internal biological clock. But, to which of the relatively stable repetitive events that take place in the human organism this clock corresponds? Many candidates have been proposed through the years: breathing rate (Münsterberg, 1889), brain cell metabolism (Hoagland, 1933), alfa waves rhythms (Wiener, 1948), heart rate (Ochberg, Pollack and Meyer, 1964), etc. None of them has resulted to be correct, or at least generalizable across different timing experience. As we will see in the next paragraphs the hunt to an internal, neurological pacemaker continues even nowadays, but none of the attempt to isolate such a clock in the brain has been successful.

Nevertheless, in the first half of the last century, the evidences for the existence of an internal biological clock were considered to be numerous. Many studies for example have shown the remarkable timing capacity of lower organisms such as plants or warms (see Fraisse, 1963) who usually react to periodical natural changes (as tide cycles, or dark/light cycles) but maintain these reaction with an incredible accuracy even when they are isolated from their usual environment (i.e. put in a box, in an experiment room where there is always light). Those phenomena seem indeed hard to explain without presuppose a sort of biological time keeping. The same can be said about the weird fenomenon of the exact timing awakening (in humans) that we considered before.

Another piece of evidence for the connection between periodical biological rhythms and the experience of time derived from those experiments in which chemical and physiological manipulation, such as the administration of a drug or the induced variation of the body temperature, has been found to affect temporal judgments. Hoagland (1933) measured the rate of repetitive beats performed by his wife under fever and found that the more the temperature was elevated the more the rate was faster. Some years before, Françcois (1927) observed similar effects inducing body temperature variation (using the technique of diathermy) to healthy subjects. Hoagland combined François' data with his own results and observed that the temporal rate estimation plotted against the increasing temperature values approximated a straight line, suggesting that a unitary chemical mechanism was responsible for those temporal judgment. Although the evidences for Hoagland's interpretation are mixed (several experiment failed to replicate the effect of temperature on timing rate, see Ornstein, 1969, p. 32-33), they are still taken into account by modern supporters of the internal clock theory (Treisman, 1963; Wearden, 2005; 2008). Moreover, it has been proved that the effect of drugs, like psilocybin or LSD induces time dilation (see Ornstein, 1969 and Fraisse, 1963 for a review). Often these effects are been interpreted as if the chemical modulation induced by the drugs affects the biological clock speeding up (or slowing down, in case of other drugs) the rate of the time keeper.

As Ornstein (1969) pointed out in his review of the argument the early attempts of psychologists trying to study temporal experience resulted in a maze of possible biological mechanisms being imputed to represent a sort of organ of time keeping, an internal clock, supposed to be the basis of our temporal experience. One of the error at the basis of this unfruitful approach consisted in treating temporal experience as a sensory process:

> "If time were a sensory process like vision, then there would exist a 'real' time independent of us, and we would have an organ of time experience such as the eye. Some have identified 'real' time with the clock time of minutes, seconds, etc. They forget that our clock is but arbitrary means of defining time. It is a convenience, used as an arbitrary standard useful for meeting and making arrangements. But it is not 'real' time any more than the 'time' of boiling rice is 'real' or the cesium clock is 'real'. One may measure out one's life in coffee spoons as well as with a calendar, an hourglass or with pots of boiling rice. A 'time basis' of duration experience founded on the interval at which experiential and clock times sometime coincide is

of no special significance, Additionnaly, this interval is not even consistenly estimated." (Ornstein, 1969, p. 34)

Ornstein's argument reveals the substantial arbitrariness under the choice of a physiological process as a 'chronometer'. Why the heart rate, or cell metabolism and not toe-nail growth? Asked Ornstein with a touch of irony. In principle any physiological continuous or rhythmical process can be denoted as a chronometer (we can discover for example that psilocybin speeds up hair growth), thus the notion of chronometer or internal clock suddenly become useless. The metaphor of the 'sense of time' is just a bad metaphor, eyes capture electromagnetic radiation, ears capture mechanical waves in the air, what should capture the organ of time? Entropy fluctuations? What actually captures a normal mechanical clock?

Although the metaphor of a 'biological clock' can be adequate to explain periodic physiological rhythm (like circadian rhythm) and the behavior connected to them, it doesn't seem to be useful for an explanation of time experience. For this reason some authors has preferred to consider a model of time experience based on cognitive processes of information instead of bio-chemical rhythms.

## 3.2 Cognitive models for duration experience

Considering that the first approach to the study of time, characterized to what has been called a posteriori *chronobiology* (Block, 1990) aimed to define the chemical or biological basis of an internal clock, it is not surprising that the fist coherent cognitive models for temporal experience born in reaction of this tradition.

Most of the contributions that we are going to review are focused on explaining how the experience of duration take place in our mind, and to built up cognitive models that can be well representative of the process of duration estimation. The study of duration cannot be exhaustive of the complex phenomenology of temporal experience, (which includes for example simultaneity and succession, irreversibility, temporal orientation, temporal direction, etc.) but it is often considered, according to John Locke, one of the more basic aspects of temporal experience on which more complex features of the psychological time can be built up. In spite of its apparent triviality as ubiquitous phenomenon, subjected to apparently simple judgment like “A is shorter than B” or “C lasts more than A”, we will see that the empirical as well as the theoretical investigation of duration evaluations is subjected to a number of conditions, distinction and contingencies (as the type of memory involved: working or long term memory; the type of evaluation: prospective or retrospective; the type of temporal interval investigated: sub- or supra- second; the strategy employed: counting, tapping, etc.) that succeeds in the proverbial philosophical and scientific paradox to make extremely complex very simple things. Nevertheless, psychologists and cognitive scientist seem to have sufficient stamina to continue in this inglorious *fatigue*, and don’t seem to show any sign of weakness.

### 3.2.1 Fraisse

Fraisse, for example, suggested that our experience of time is based on the experience of change, in terms of both physical and psychological changes. He agrees with Ornstein that temporal experience cannot be approached as a kind of sensory experience, but that could be better understood as the product of the constant processing of information carry on by the nervous system. The philosophical starting point is exquisitely aristotelian:

> “Aristote avait déjà note «que le temps… n’existe pas sans le changement»” (Fraisse, 1957, p. 3)

*Change* is an abstract concept that can be referred both to sensory or physiological processes (i.e. the change of the temperature of my body) and to psychological ones (i.e. changes of ideas, representation, sensations, etc.). According to Fraisse (1957) “la longueur d’une durée dépend du nombre de changements que nous y percevons” (p. 231), a point of view that he describe as close to Condillac, when he says that “le temps n’est fait que de la succession et du nombre des impressions ressenties par l’organe ou évoquée par la mémoire” (p. 231) or to William James, according to which it is the richness of its content that make the length of time. More specifically we can say that all that contribute to augment or diminish the density of perceived changes has the effect to extend or contract the apparent duration. Paying attention on the flow of time it is nothing more than allocating the attention on the changes that take place in that period. For this reason a long and boring wait is perceived to be longer than a fun activity, because in the first case our attention can focus on all the changes happening inside and outside of us, changes that in the second case would be ignored:

"Ne rien faire, ce n'est pas créer le vide mental; ou bien c'est attendre la fin, et de l'attente nait le sentiment de temps dont le corollaire est l'allongement de la durée; ou bien c'est observer tout ce qui ce passe pour remplir la durée. Tout travail au contraire, quel qu'il soit, implique un certain but, même si pour l'atteindre il faut effectuer des taches parcellaires" (Fraisse, 1957, p. 241). For the same reason a continuous task appear to be shorter than a discontinuous one, in which more changes happen; empty (auditorily) temporal intervals are perceived to last less than full temporal intervals; intense stimuli are judged to last more than weak stimuli (because there is more solicitation and a greater cognitive input); and as the number of stimuli presented within a temporal interval increase, the experienced duration lengthen (Roelofs & Seaman, 1951; Fraisse, 1961). In this model both perceptual and psychological changes constitute the substrate over which our experience of duration is built on. When both internal and external factor are operating, the choice to focus on one in respect to the others largely depends on the context:

> "Devant le changement je puis m'attacher à la succession des événements qui se produisent comme en dehors de moi ou, au contraire, aux seuls retentissements qu'ils ont en moi. En lisant un roman, je puis juger des changements par le nombre de pages que je tourne ou, au contraire, ne m'attacher qu'aux péripéties que je vis avec les héros de l'aventure" (Fraisse, 1957, P.230)

In any case, the density of change is referred to the cognitive load, not to the work of a sensorial organ (that can be ignored) or to the variation of an external 'real time' (that may not exist). To sum-up, what make this psychological model critically different from the 'time sense' approach, is that temporal experience is related to human information processing instead of perceptual data or physiological regularities. Moreover, it refuse the idea of a time itself that exist in the universe independent from any observer, and embrace an epistemological view[45] according to which time is a mental construction based on the events (changes) that take place, but not determined by this events. This psychological model can explain also for those phenomena of time distortion induced by drugs consumptions that we approached before, and that seems strongly compatible with a biological clock. Drugs consumption usually increases the sensitivity to the stimulus array and the number of mental images that are processed in mind. Fraisse reported that, for example, "sous l'éffect du hashish, la tête est semblable a un vulcan" (p.243). Keeping in accounts the subjective nature of this reports, and the large variability of the effects, Fraisse concluded that roughly, products that speed-up vital functions entail an overestimation of time, whereas relaxing substances have the reversed effect, because:

> "Il est vraisemblable de penser que les produits excitants entraînent une plus grand activité mentale, tandis que les produits inhibiteurs l'appauvrissent" (Fraisse, 1957, p. 244)

Physiological variations due to drug consumption affect temporal experience only from the moment in which they interfere with the mental cognitive processes of information. When more stimuli are registered duration would lengthen, when less changes take place in the process of information the duration would be shortened. Something similar, according to Fraisse, happens with the dreams. It has been experimentally verified (see Fraisse, 1957 for a review) that time slow down during the dreams in respect to the awaken state,[46] so that a dream that could not be longer that a bunch of seconds or minutes it seemed to be very long because of all the events, actions, and sensations that has occurred. When we dream the brain activity is still high, and the absence of the relatively stable perception of the outside world allows the fast succession of different images apparently weakly related and increases the density of changes in the mental activity. Similar experience has been described in studies on hypnosis (Fraisse, 1957).

According to Fraisse, humans have no specific 'time sense', in terms that one has not direct experience of time and such. It is not time itself, but the continuous changes that we perceive and experience, inside and outside of us, that produce

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[45] See 4.2

[46] But see Dement & Kleitman, (1957) for different conclusions.

temporal effects, experience or perception. This point of view introduced important innovations in the study of time because:

> “Duration may then be studied without reference to any sort of external clock, ‘biological’, ‘chemical’ or the ordinary mechanical clock. The experience of duration of a given interval may be meaningfully compared only with other experiences” (Ornstein, 1969, p. 40)

Then, according to Fraisse’s theory of time, each experience of duration, compared to others experience of duration, depends on the quantity of changes processed in our conscious mind. More changes (images, mental content) are processed more the duration lengthened, and vice versa.

### 3.2.2 Ornstein

Ornstein (1969) proposed a memory-storage model for duration estimation that he baptized the *storage-size metaphor*. Like Fraisse, Ornstein is a strong opponent to the internal clock model based on a epistemological approach that conceive temporal experience as a perception process, even if a sensory organ for temporal perception doesn’t exist. Ornstein categorizes Fraisse’s approach as a variety of ‘short-term storage theory’ in which the amount of change, or mental images, registered in consciousness modulates the experience of duration. The duration estimated, or merely experienced, therefore, depend on the information stored-in by the short-term memory or the working memory, during the experience of a given temporal interval. According to Ornstein, in this model is active an ‘input register’ which “would monitor and measure the information input and be the basis for the experience of duration” (Ornstein, 1969, p.38).

But, Ornstein noticed that often the experience of duration involve the recall of a relatively long temporal interval, too long to be stored in the working memory. Therefore, temporal information about the duration of an interval should be stored somewhere else in the long term memory in order to be retrieved when the interval itself is finished. For example, a phenomenon that ‘short-term storage’ theories cannot account for, is the so called *time-order error*. If a subject is asked to estimate the duration of two consecutive temporal intervals, the first one is often estimated shorter than the second (See for example Woodwhort and Schlosberg, 1954). According to Ornstein, Fraisse's model cannot explain this effect, for which the first temporal interval is shortened relatively to the second. In fact, if is the information stored during the encoding process of the first temporal interval, that stay at the bases of its experienced duration, then what happens during the second interval should not be able to modulate the apparent duration of the first one. Similarly, being the second temporal interval a repetition of the first one, it is unlikely that a more amount of change, that would lengthen the second interval, is detected. Actually, it is more plausible the reverse, being the first interval a relatively new event. In these terms the input register cannot be responsible for the effect. According to Ornstein, the duration of the temporal interval stored in memory is still subject of variation. For example, a constant ratio of decay of input information stored in the long-term memory can explain why older inputs seem to be shorter than newer ones. Moreover, this approach opens to the possibility that external factors could influence the experienced duration even affecting the already stored information, and not only the information processing at the moment of encoding.

In others words, the two theories (*input register* and *storage-size*) are of similar order, the difference is that the 'input register' holds that the remembered duration is determined by the input information during the temporal interval, while according to the 'storage-size' model, are the information that remain in storage that determine the remembered duration.

Ornstein provided several data supporting not only that an increased stimulus complexity imply lengthened duration evaluations (i.e. for example, more organized (easily coded) intervals are judged to be shorter that more complex intervals, Ornstein, 1969, Exp.3 and 4), but also that factors other than input, like coding processing, can affect the remembered duration of an interval: for example, given a stimulus array under particular conditions, we should expect that subjects that can respond automatically to these conditions, because more experienced, would be less aware of the stimulus array and then experience a shorter duration than subjects that cannot respond in the same way (See Ornstein, 1969, Exp. 5-6). Moreover, even factors that can modify the size of the storage after that the input is registered, could modulate duration experience and evaluation. This last condition, especially, is viewed as theoretical line of demarcation from the others variant of cognitive approaches such as the 'short-term storage theories'. The time-order effect described above might be taken as evidence of this post-storage kind of effects (see Ornstein, 1969, exp. 7), and Ornstein's experiments 8 and 9 (Ornstein, 1969) indeed show that providing means of recoding, like a new procedure to organize previous complex information, can reduce the size of the storage and therefore reduce the remembered duration of the temporal interval in which the information has been encoded. In experiment 8, for example, participant heard a 1-minute music tape and then saw for the same duration a complex figure. After that, in one condition subjects had to compare the duration of the figure-watching with the duration of the music tape, on the other condition, subjects were provided by an interpretation of the complex figure (i.e. "What you have seen was the word 'man' written over its mirror image") before doing the duration comparison. Results show that subjects in the second condition reported shorter duration evaluation (compared to the duration of the tape) than subjects in the first condition, providing evidences that the experience of duration can be reduced after the temporal interval is over, by changing (recoding) the storage-size of the interval in memory.

Ornstein conclude that the storage-size metaphor is able to explain several empirical data that the 'biological clock' and the 'input-register' cannot account for (at least altogether). Namely: the lengthening of duration under LSD or other excitant drugs, the effect of a 'successful' or a 'failure', the effect of the complexity of the stimuli, the time-order effect, the effect due to the coding of a stimulus array and to the re-coding after the interval is over (Ornstein, 1968, p.110-111).

Nevertheless, in spite of the conspicuous amount of data provided by Ornstein to support his theory, others empirical evidences seems to be incompatible with the storage-size metaphor.

For example, it turned out that the time-order error occurs in both the order directions. The effect described by Ornstein, in which the first temporal interval is experienced as shorter than the second temporal interval, it's called the negative time-order effect. But, in other studies that used similar methodology (Block, 1978; Hogan, 1975) a positive time-order effect (in which the first interval is judged to be longer than the second one) has been described. The storage-size metaphor proposed by Ornstein can explain for a negative time-order error, in which the second of two intervals is remembered as longer, as caused by "items dropping out of storage" (1969, p. 107), but it cannot explain the occurrence of the negative time-order effect (Block, 1979).

Moreover, it has been noted that the definition of stimulus complexity is quite vague, and makes it difficult to compare the complexity of different kind of stimuli (Block, 1979). Indeed, other studies have failed to find an effect of stimulus complexity (whatever it means) on duration estimation (i.e. Block, 1974; Predebon, 1984) and other reported conflicting results (see for example Block, 1979). For example, Predebon (1984) did an experiment in which subjects listened a prose passage (from Bransford and Johnson's (1972), experiment IV, sentence material) on a recorded tape. Before the listening, to half of the subjects was given the prompt "The tape recording will be about making and flying a kite", the other half did not received any prompt.

The thematic information given by the prompt was important because could organize into a meaningful whole a sequence of, otherwise, semantically unrelated sentences (i.e. A newspaper is better than a magazine. A sea-shore is a better place than the street. At first it is better to run than to walk. Even young children can enjoy it. A rock will serve as an anchor. Etc.). As expected, subjects who received thematic information before listening the tape performed better in memory and comprehension tasks, on the other hand, the manipulation did not influence the remember duration of the prose passage.

These early cognitive models proposed by Fraisse and Ornstein seem to be incomplete, and insufficient to account for the complexity of the psychological experience of time and, in particular, of duration. Nevertheless, they enormously contribute to the study of time in psychology and cognitive sciences introducing a new way to study temporal experience.

In the last decades, many new cognitive models of the experience of time have been proposed. What is following, it is a review of the ones we consider more significant.

## 3.4 Recent models in cognitive science

No existing model can handle all the variety of experimental evidence in the psychology of time, and things doesn't seems to change to much if we restrict the focus on the experimental studies of duration. Moreover, an extensive review of the empirical data on the experience of time and duration often provides us contrasting and contradicting evidences as well summarized by Zakay and Block:

> "People may estimate filled durations as being longer than empty durations, but sometimes the reverse is found. Duration judgment tends to be shorter if a more difficult task is performed than if an easier task is performed, but again the opposite has also been reported. People usually make longer duration estimates for complex than for simple stimuli, although some researchers have found the opposite." (Zakay & Block, 1997, p. 12)

One way that has been found to make sense to this large amount of data is usually to refer to particular conditions of temporal experience and the methodology used to investigate it, and the model used to explain the result. For example, for a prospective duration paradigm, when subjects are advised that they will be asked to judge, produce or reproduce the duration of temporal intervals (a condition that Block called "experienced duration", [Block, 1990]) the temporal behavior is usually explained by attention-based models (Zakay & Block, 1997), or internal-clock models (Treisman, 1984; Gibbon, Churck and Meck, 1984); for a retrospective duration paradigm, when the subjects are unexpectedly asked to make a duration judgment about a previous event (the paradigm used by Ornstein, and to which Block referred as "remembered duration"), is usually explained by *storage-size* or *memory change models* (Ornstein, 1969; Block, 1990). Usually internal clock models, often judged insufficient to explain the complexity of human temporal behavior and cognition are rather used to explain temporal behavior and capacities in non human animals (Gibbon, Churck and Meck, 1984; Weirden, 2005). Three of the more influent cognitive model of psychological time are here reviewed, without having the pretension to be exhaustive.

### 3.4.1 Memory-change models

The memory-change models (Block, 1978, 1989, 1990; Poynter, 1983; Predebon, 1984) can be considered an attempt to ameliorate the storage-size models (Vicario, 2005). Following Fraisse (1963, 1984), the focus is replaced on the quantity of changes that take place in the context of the encoding of a temporal interval. According to Block, the remembered duration is a direct function of the remembered amount of change in the cognitive context. The contextual aspects that determine the amount of cognitive change are, for example, the number and complexity of external stimuli, internal sensations, characteristics and previous experience of the subjects, emotional reactions, the kind of activities in which the subjects are engaged and the strategies of information processing that they are using. In these models the aspects that modulate the remembered duration of events is extended to all the mental events (cognitive changes) that occur during the time period (encoding) and not just the ones that modulate the complexity of the stimulus event per se. In fact, according to Block (1989) the manipulations of coding processes will affect remembered duration only if they correspond to a variation of the overall amount of cognitive change during the encoding of the temporal interval (i.e. non-coded, and therefore more complex stimuli, require a more complex sequence of interpretation than a less complex ones). If the coding given to the subject don't cause a variation in the contextual changes during the experience of the events occurring in a temporal interval, the remembered duration of the interval wouldn't be affected by the complexity of the stimuli (measured along the coding/not-coding conditions), as occurred in the experiment presented before (Predebon, 1983; Block 1974, but see also Block, 1978) that seems to contradict the storage-size hypothesis. Moreover, Block (1989) offers an alternative explanation for Ornstein's finding that coding instruction given after the experience of the temporal interval (i.e. the instruction "What you have seen was the word 'man' written over its mirror image" given in Exp. VIII, after a complex figure) can modify the remembered duration reorganizing the information stored in memory. According to Block, the subjects that receive the coding instruction simply did not retrieve all the information about the stimulus (contextual change) at the time they made the duration estimation (Block, 1989).

Different experiment has been done to support the contextual-change hypothesis (Block, 1974, 1978, 1982; Block and Reed, 1978; Poynter, 1983). For example, Block (1982) conducted 2 experiments (Experiment 1 and 2 in the paper) to see if task-irrelevant environmental change could constitute a source of contextual cognitive change and affect the remembered duration of a temporal interval. An equal number of words were presented in the same way during each of two temporal intervals. The environmental context (room, experimenter, form of the material) was manipulated either between the presentation of the two temporal intervals (disruption only), both between presentations and during the second presentation (disruption and change), or remained the same across the two presentations (see Block, 1982, for more details). According to the results, the remembered duration of the second temporal interval (D2) was longer for the subjects in the "disruption and change" conditions compared to the subjects in the "disruption only" condition, and, in the latter condition, D2 was remembered as longer than in the basic condition in which neither 'disruption' nor 'change' occurred.[47] Other evidences for how transient changes in encoded contextual information can influence temporal judgment come from Poynter (1983). In this experiment participant heard a list of unrelated nouns intermixed with a number of U.S. president's last names (3-4 minutes). In some cases president names and other nouns were evenly distributed along the presentation, in other cases the U.S. president names where presented either at the beginning or at the end of the list. Participants have to try to remember all the items presented, paying particular attention to the president names. Moreover, a duration judgment on the length of the presentation was asked afterwards. Results show that the presentation was remembered to last longer when the different items were evenly distributed than when they were grouped at the beginning or at the end of the list according to the item's category. Poynter suggested that the remembered duration is related to the number of interval events recalled or recognized. In the non-grouped condition the president names were markers that served to segment the temporal experience, and the more segmentation is experienced during a temporal interval, the more is its remembered duration. Moreover, since no difference were found, across conditions, in word recognition and recall, Poynter concluded that even

[47] The positive time order error between D1 and D2 was reduced in the 'disruption only' condition and eliminated in the 'disruption and change' condition.

when the items presented in two intervals of the same duration are remembered in the same degree, the intervals are not remembered as to be equal in duration as well. According to Poynter, the storage-size model cannot predict these results.[48]

Even if it's capable to explain a considerable amount of empirical data, at least in the studies that adopt a retrospective duration paradigm, the memory-change models present some important limitation. As noted by Predebon (1984), one problem with these models is the lack of information about which kinds of factors are likely to affect cognitive context, the conditions (external or internal) under which such factors will be elicited and the relative importance of these factors in determining changes in the cognitive context. For example, in another experiment, Pedrebon (1988) presented to the subject a relatively long temporal interval (40 sec) in which images were displayed on a computer screen. Subjects were assigned to one of three conditions. In the fists condition subject saw on the screen an ambiguous figure (the duck/rabbit figure) during all the temporal interval; in the second condition subjects saw a unambiguous figure of a duck for all the temporal interval; in the third condition subjects saw two unambiguous pictures of a duck and a rabbit, presented in alternating sequence. The remembered duration in the third condition was longer in respect to condition 1 and 2. On the other hand, no significant difference in retrospective duration was found between condition 1 and 2, even if all the subjects reported to have experienced perceptive fluctuation between one visual configuration and the other during the presentation of the ambiguous figure. These results were confirmed in a second experiment (see Predebon, 1988, supplementary experiment).

Predebon (1988) concluded that stimulus-based change events (alternating figure condition) but not perceptual-cognitive change events (ambiguous figure condition) modulate remembered duration. We don't know if this prediction has been confirmed (the second experiment presented in the second chapter of this thesis partially challenge this conclusion), but the unexpected outcome of this study well represent the difficulty, remarked by Predebon himself, to determine the conditions under which different factors imply changes in the cognitive context. In a commentary on the memory-change models Fraisse has written that:

[48] But, Poynter admits the possibility that the storage-size was not adequately measured (Poynter, 1989).

"it may be that the S[ubject] in certain cases takes into account the objective number of changes in the situation, for example, the number of slides projected, but that in other cases it would be the number of changes memorized in an individualized manner that he takes into account." (Fraisse, 1984, p. 20)

This distinction may suggests a practicable *post hoc* explanation for these kind of results, but, in our opinion, has the defect to make (the theory related to) these models very difficult to falsify empirically. Moreover, how can we clearly distinguish the two conditions described by Fraisse in the experimental setting?

This last question highlights another important problem of the memory-change model, noticed already by Block (1990, p. 25) and remarked by Vicario (2005, p. 162). The explanations of the memory-change models (but this criticism can be extended also to the storage-size models) are often circular, because they don't suggest any independent method to measure the quantity of change that take place in the cognitive context. I other words, the only way to measure the amount of cognitive change is the remembered duration, and vice versa.

### 3.4.2 Pacemaker–accumulator models

Another, very popular way to explain the experience of duration and the consequent behavior consists in resurrecting the internal clock model under cognitive (as well as neurobiological) dressing. The internal clock models have been proposed especially by contemporary behavioral psychologist, in attempt to explain duration-related animal behavior, and are particularly useful to model prospective time judgments.

The first significant attempt to situate the 'internal clock' within the framework of a more complex cognitive system that includes both memory and decision making mechanisms can be find in Treisman (1963). Treisman's model, consists in a pacemaker which delivers relatively constant pulses; a counter, or accumulator, that 'records' and 'store' the pulses as a reference memory; and a comparator, a mechanism to compare the values stored in the counter (see fig, 1).

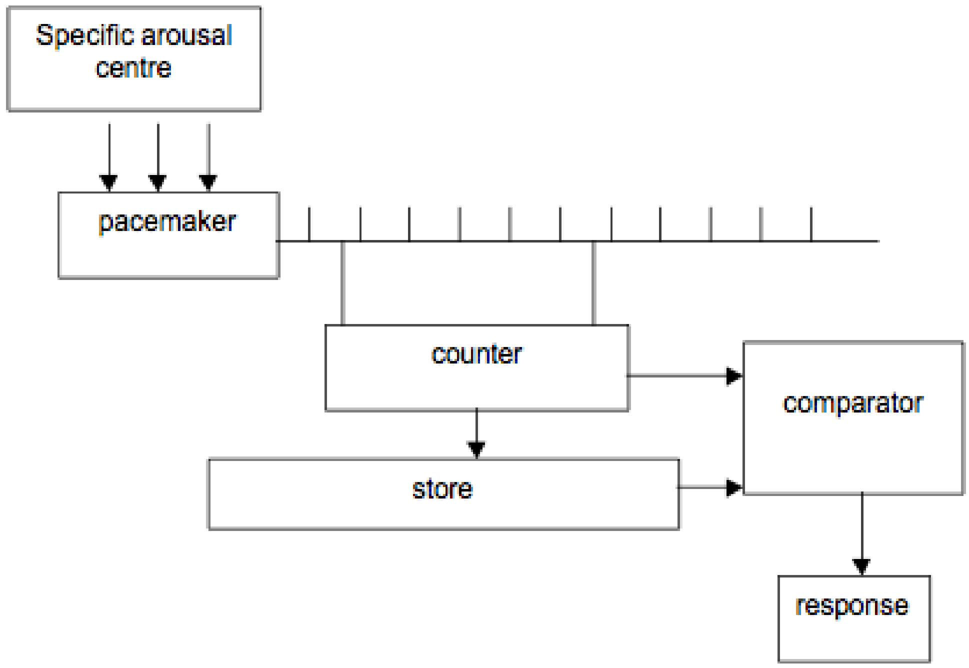



Fig.1 Treisman's model of the internal clock (Treisman, 1963)

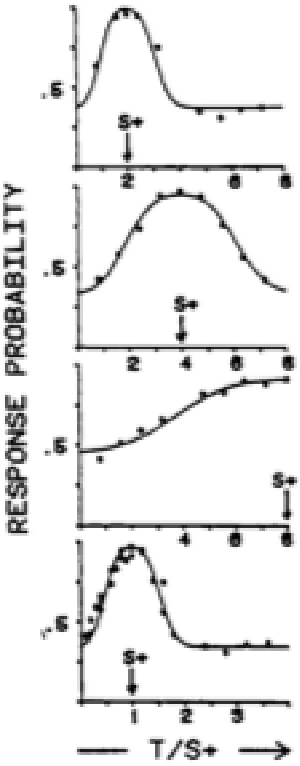
As we can infer from the picture, the pacemaker in Treiseman's internal clock should be sensitive to arousal activations. Higher arousal activations speed-up the pacemaker rating with the result of a longer estimation of the interval duration (compared to the duration estimation with a normal arousal level). Different lines of evidence have been provided to support this claim (See Treisman, 1984 for a review), among the most general evidences we can ascribe the fact that duration estimation is longer (the pace-maker speeds up) for more arousing auditory stimuli than for visual ones; for more intense stimuli than weaker ones; and for stimuli that strike fear or danger compared to neutral ones (Treisman, 1984).

The functioning of Treisman's internal clock can be summarized as following: in a temporal reproduction task, a target duration of an event, like a sound, produced by a computer, has to be reproduced by the subject as the interval between two clicks. The number of pulses produced by the pacemaker in correspondence to the duration of the sound are grouped by the counter and stored in the 'store'. Then, the reproduced interval will terminate when the number of the pacemaker pulses counted by the counter (starting from the first mouse click) will be equal to the value of the standard duration retrieved from the store. The judgment of equality will be made by the comparator mechanism.

More recently (Gibbon, Churck and Meck, 1984) a similar, but more detailed, model of internal clock has been proposed in the context of the *Scalar Expectancy Theory* (SET). This model has been designed to explain temporal behavior in animals such rats and pigeons. These and others animal species seems to have relatively accurate timing capacity. For example, in one of the simplest experiments, performed by mice, the light in the experiment box is turned off for a given duration, 'T'. Then a retractable lever is inserted into the box. The lever, if pressed, will reward food only after a specific, target duration (S+), say for example 4 seconds. If the box has been without light for a duration different of 4 seconds no food will be provided after the lever pressing. Across different trials rats come to respond with higher probability when T is around 4 seconds, and with decreasing probability for longer or shorter durations. The distribution of the given responses is bell shaped with the peak around the target duration. In figure 2 is displayed an example of different distributions around different target durations (S+). In each panel the spread of the data is proportional to the size of S+. In other words the standard deviation around the mean of the distribution ($\mu$), that is usually slightly different to S+, covaries with the size of $\mu$, so that the rapport between standard deviation ($\sigma$) and the mean of the distribution $\mu$ remain constant:

$$\sigma/\mu = k$$

that property of the timing behavior is usually referred to as the scalar property (from which the name SET), and it is similar to the Weber law.




Gibbon, Church and Meck, 1984, *Annals New York Academy of Science*

Fig. 2: The plots show how the rapport between the standard deviation and the mean remain constant. An increasing in magnitude of the mean (S+, the duration after which the food is provided) imply a proportional increasing of the spread around the mean.

The scalar property is explained by an internal clock similar to the Treisman's clock (Fig. 3).

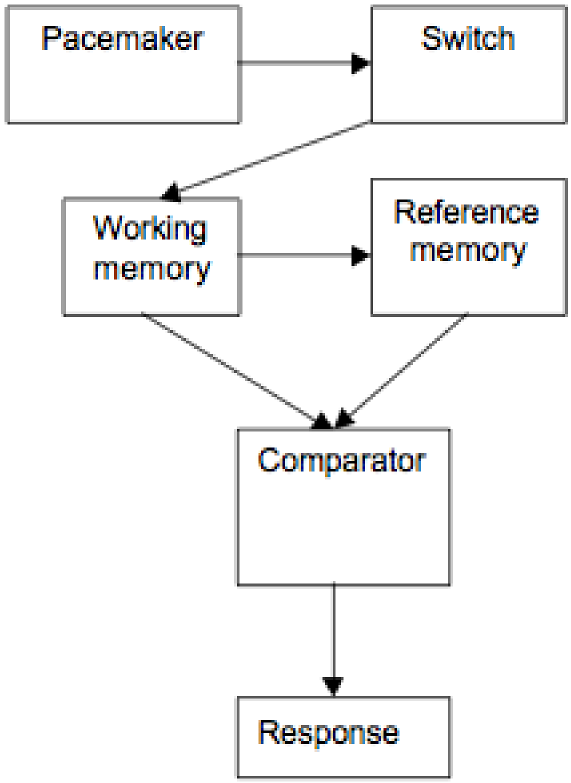



Fig 3: SET internal clock (Picture from Wearden, 2005).

The pulses are emitted by the pacemaker and switched into an accumulator. At the moment of the reward, the number of pulses stored (temporary) in the accumulator is moved into the reference memory. In the model, the working memory reflects the ‘raw’ representation of duration in the accumulator, and it is assumed not to be a source of variance (Gibbon, Church & Meck, 1984); in the reference memory are instead stored some kind of representations of durations considered ‘important’, for example because associated with a reinforcement. Each time the animal receive a reinforcement, he adds the representation of the duration associated to the reinforcement to the others ‘important durations’ in the reference memory. Reinforcement after reinforcement, the reference memory will contain a distribution of values representing the reinforcement times.[49]

[49] More specifically, when the reinforcement is delivered, the value in the accumulator is multiplied by a random factor (k*) and stored in the reference memory. Because the pacemaker rate $\lambda$ and the memory factor k* are considered to be random Gaussian variables, the value in

For each temporal interval presented, the animal decide whether or not to press the lever, extracting one sample duration among the distribution of ‘important intervals’ stored in the reference memory, and compare this value to the amount of pulses temporary stored in the accumulator for the current trial.

The scalar property of the system derives from the assumption that the error of the accumulator (due to the variability of the pacemaker rate) or the variability across the different ‘important values’ stored in the reference memory, is proportional to the magnitude of the temporal interval that is associated to the reinforcement. The final decision is taken through a comparator mechanism in which the current temporal interval is compared to the stored reference to see if they are ‘close enough’ according to a specific threshold.

The supporters of this model highlighted numerous qualities of it: it is straightforward (Buhusi & Meck, 2005); it allows to make testable prediction and it’s usually successful (Gibbon, Church & Meck, 1984); it provides a model that is suitable to explain timing behavior and capacities across tasks and species (humans included); it is modular, having at least three clearly separated components (clock system, memory system, decision system) that can be singularly manipulated in experimental settings with the possibility to determine the correspondent cerebral structures and neurotransmitter system (Buhusi & Meck, 2005; Wearden, 2005; Church, 1999).

For example, several studies that used pharmacological manipulations has provided evidence for a dissociation between the clock system (pacemaker-accumulator), which seems to be affected by drugs that stimulate the dopaminergic system, so that the pacemaker rate speeds up with higher level of dopamine; and the memory system, mostly affected by cholinergic manipulations (Meck, 1996; Buhusi & Meck, 2005).

The popularity of the SET theory in explaining timing behavior in animals of different species contributed as well to revitalize the interest on the old theory of a human internal clock (see 3.4.3 and 3.5). If the Treisman’s model of internal clock did not reach a good popularity at its time (Warden, 2005), the opposite can be said for the

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the accumulator at the end of an interval and the value stored in memory also will be variable, even when the timed interval has constant duration. Both random variables induce scalar variability in the subject’s representation of time. (Gibbon et al., 1984)

SET model and its human applications. This success is due, at least in part, to the interest of the neurosciences in finding the cerebral analogs of the SET components (See for example, Gibbon et. al., 1997; Buhusi & Meck, 2005; 2009).

Some studies has shown how temporal estimation and reproduction in human subject follow the Weber law, a trade-mark of the Scalar Expectancy Theory, in both adult and children (see Warden 2005 for a brief review). A particular focus of interest, has been attempts to change the rate of the pacemaker of the internal clock in human subjects. Following Treisman idea of an arousal-based pacemaker, different studies have tried to "speed up" the clock manipulating the arousal activation. Treisman, Faulkner, Naish, and Brogan (1990), for example, have shown that the increasing of the arousal activation caused by presenting to the subjects a train of repetitive stimulations (e.g. a sequence of clicks) increases duration estimation of given temporal intervals. Even if this effect has been confirmed in subsequent studies (i.e. Penton-Voak, et. al. 1996; Burle and Casini, 2001; Droit-Volet and Wearden 2002; all quoted in Wearden, 2008) the connection between repetitive stimulations and arousal activation doesn't seem to be unequivocal (Wearden, 2008) leaving the doors open to alternative explanations.

Some scholar, like Wearden, in the attempt to adapting SET to human behavior and cognition, have extensively criticized the central role given to the reference memory in the classic formulation of SET (See, Wearden, 2003; 2005). According to Wearden, in the original SET the principal source of variability (and scaling) are the various 'important durations' stored in the reference memory. Let's consider for example the case of the simple experiment described at the beginning of this paragraph, in which a mouse could press a lever after that the light in the experimental box was turned-off for a certain duration (t). The reward was provided only when the duration of the dark-period was 4 seconds (S+), but not when the dark lasted longer or shorter. The mouse will learn to press the lever only after the criterion duration S+, with some variability. When the animal press the lever after a period of dark *t* that is different from S+, the source of error has to be track down to the reference memory, and not to the current estimation of *t*.

> "On some trials, *t* is remembered as being longer than its real value, and on other trials shorter, but these instances are stored in reference memory, which over a large number of training trials develops to the form of a Gaussian distribution, with mean *t* and some variability. The animal performs by sampling from this memory distribution on each trial (with each sample producing a slightly different value), and uses the sample as an "estimate" of when the reward is due. The estimate varies from trial to trial, and so does the behavior as a consequence. The variability here arises from *memory* variability and not from *timing* variability." (Wearden, 2005, p. 23)

According to Wearden this conclusion is biased by the kind of training to which animals are subjected, and it is not adequate to explain human timing behavior. Indeed humans can perform very well in this kind of timing tasks even if the criterion duration is presented just a few times. A condition for which the construction of a Gaussian distribution of samples in the reference memory seems implausible, suggesting that the source of the scalar variance of human timing behavior has to be a different one. Wearden and colleagues (Lejeune, Ferrara, Simons, & Wearden, 1997; Wearden, 2003, Wearden & Bray, 2001) even recognizing the importance of the effect of memory on timing capacities, prefer to put the focus of the scalar variability on the variation of the pacemaker speed from trial to trial, and on the accumulator in the working memory (Wearden, 2003). Moreover, they suggested that the reference memory in humans (and possibly in animals as well) do not consist in an "extensive distribution of stored time values" (Warden, 2003, p.7) but on a single standard with upper and lower limits that will be replaced if, due to the variation in the pacemaker-accumulator system, another significantly different standard value is presented to the reference memory.

This model has been called *perturbation model* (Wearden, 2003), and it is in competition with many others models that has been proposed as a *variation on the theme* of the classic SET (e.g. *The multiple-oscillator theory of timing* (Church & Broadbent, 1990); *The relative time sharing model*, (Buhusi & Meck, 2009a,b)) and others alternative models of animal and human timing (i.e. *the behavioral theory of timing* (BeT) (Killeen, 1991); *the learning-to-time* (LeT) *model*, (Machado et al., 2009); *the multiple-time-scale* (MTS) model of habituation, (Staddon & Higa, 1999); and others). Unfortunately, the space prevents us to consider them all in this review.

Indeed, the internal clock models have regained a central role in the psychological, behavioral and neurobiological literature, and are probably the most popular models nowadays. To conclude, we will skip the specific problems related to the different ways to explain how the internal clock (or clocks) works, and we will focus on more general criticisms.

The internal clock metaphor seems to be as popular as it is problematic. For example, Block (1990) pointed out that this model does not take into account how various activities (such as strategies), that an organism (either human or not) is performing during the experience of the temporal intervals, influence his time-related behavior.[50] Moreover, this model is not able to explain the effect of attention on psychological time (Block, 2003, p.44), effects that are well documented in many studies with human participants (see next paragraph).

Another fundamental problem is that, despite a tremendous number of studies in cognitive neuroscience, the neurobiological basis for such an internal clock has never been found. No constant-rate pacemaker has been identified in the brain.[51] Of course, this gap could be filled by future research; nevertheless, it is possible that for theoretical and epistemological reasons such studies will reveal themselves to be problematic in principle. According to Block (2003), the scalar property of timing behavior, remarked by the internal clock models, is typical of many different dimensions for which Weber's law obtains. What it is unique for time, in this model, is the presence of a pacemaker and an accumulator and, with slight modifications (such as the substitution of the pacemaker rate with a repetitive external signal) the 'scalar-timing' model could become a 'scalar-perceiving' model (Block, 2003, p. 44). Indeed, if almost any repetitive external movement or signal can be taken as a time-keeper, the same is true for almost any internal repetitive movement or signal. The criticisms advanced by Ornstein (1969) to the old biological-clock models are still relevant. According to which criteria can we judge any relatively stable physiological or neurobiological rhythm to be

[50] Block quotes Pouthas (1985) who provided evidence that children often use an 'external clock' to time temporal intervals. They engage themselves in various repetitive movements that take the appropriate amount of time while they are waiting for the reinforcement. (Block, 1990, p. 17).

[51] Moreover, according to Block (1990), we should ask the apparently trivial question: "why human duration judgments are sometimes so inaccurate, especially for an organism that is said to possess an internal clock?" (ibid. p. 18).

a chronometer? Paraphrasing Ornstein's irony we could ask why the tonic thalamic tuning or any other cyclical neural activation should be a better time-keeper than hair or toenail growth? Moreover, if such a temporal system in the brain exists, why hasn't any neuropsychological patient with a total selective temporal impairment been described yet (Cappelletti et al., 2009)? Why can nobody become selectively 'blind' to time the way it is possible to become 'blind' to pain, sounds, touch, movement or visual stimulation? The internal clock model is based on our understanding of temporal knowledge as a sensory process, but the above questions point out that clearly it is not. Of course, it is possible to suggest that not a single clock, but multiple clocks are present in the brain (Buhusi & Meck, 2009b) and they are used in different situations according to the context (e.g. length of temporal intervals, sensory modality, particular behavior, etc.). This is a reasonable possibility but, on the other hand, it becomes difficult to find the correct criteria according to which enumerate the different clocks, with the risk of an uncontrolled proliferation of internal pace-makers and accumulators which allow us to ask, with Richelle et al. (1985, p. 90), the provocative question: ''Why not admit that there are as many clocks as there are behaviors exhibiting timing properties?'' We agree with Marchetti (2009) that if there are as many internal clocks as time behaviors and experiences, the notion of internal clock lacks epistemological and practical usefulness, given the wide variety and complexity of the experiences of time.

Other scholars have tried to overcome some of the criticisms highlighted here by proposing models of duration evaluation based on the effect of attention. Most of these models are still in the category of "timing with a timer", following the classification proposed by Block (2003). Therefore, they posit an internal-clock system subjected to the influence of attention states. We will briefly review some of these influential models before drawing some general conclusions.

### 3.4.3 Attention-based models

The attention based models attempt to conjugate the internal clock models along with the effect of attention allocation on temporal evaluation. Indeed, several empirical data suggest that the experience of time is strongly modulated by attention. These studies show that in a prospective duration judgments paradigm, for subjects engaged in a particular task during the interval time that has to be estimated, the more the task is difficult and demanding, the shorter will be the estimated duration. In other words, the subjective duration of a temporal interval linearly decrease with the increasing processing demands of a co-occurrent task. The mainstream interpretation of these results is that the experienced duration increases to the extent that subjects could allocate more attentional resources to the flow of time itself (Thomas & Weaver, 1975; Brown 1985; Hicks et al. 1976, 1977; Coull et al. 2004). For example, in a classic study, Macar, Grondin & Casini (1994), asked participant to divide their attention between temporal and non-temporal information (e.g. 25% temporal and 75% non-temporal). The results showed that duration judgments varied according to the particular division of attention that participants were instructed to use.

Zakay & Block (1997), refined the internal clock models taking into account the effect of attention allocation in duration judgments. The model they proposed is called the *Attentional-gate model* (Fig 4). According to this model, prospective timing is a dual-task condition in which attention is shared between temporal and non-temporal information processing. Block specifies:

> "Non-temporal information processing is directed toward external stimuli (along with accompanying internal cognitions), excluding attributes involving time. Temporal information processing is directed toward time-related aspects of external stimuli, as well as time-related internal cognitions (such as what is called *attending to time*)." (Block, 2003, p. 48)

The main difference between the attentional-gate model and SET is that an *attentional gate* is interposed between the pacemaker and the switch. The gate allows the pulses produced by the pacemaker to reach the switch and being accumulated only if the subject is directing his attention to the temporal information of the task (opening the temporal-gate). When the attention of the subject is directed to non-temporal information the attentional gate remain closed, and the pulses generated in that interval of 'non-temporal attention' cannot been accumulated. Therefore, the less the attentional gate is still open, the shorter the subject estimates the temporal interval.

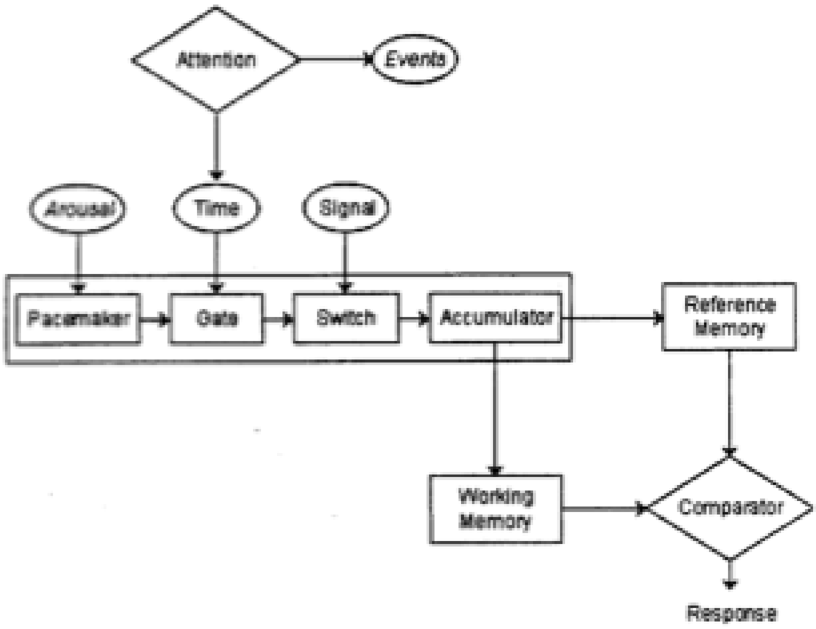


Fig. 4: Attentional-gate model. Adapted from Block (2003)

As noted by Marchetti (2009), the attentional-gate model, not only can explain for the effect of attention in explicit dual-task paradigms, but it explains as well why prospective reproductions are typically shorter than target duration: as Block pointed out, every prospective duration judgment is a dual-task condition, in which attention can be allocated, for a variable amount of time, on non-temporal characteristic of the task or the surrounding environment. In others words, it is hard for the subject to pay constant attention to the temporal information only, for all the task. During the periods of non-temporal attention, the attentional-gate remains closed, leading to a reproduction that will be shorter than the target duration.

Conceived and tested in order to adapt the internal clock model to the complexity of human timing behavior and cognition, the attentional-based model has recently been employed, with some appropriate modifications, to explain animal timing behavior as well (Buhusi & Meck, 2009a,b).

Nevertheless, this model has several limitations. First of all, as noted by Marchetti (2009), some empirical findings strongly contradict the predictions of the attentional-based model. It is the case, for example, that shocking or un-expected events are sometimes estimated to be longer in duration than neutral stimuli (Angrilli et. al., 1997). A prediction based on the attentional-gate model should instead be the opposite, since the shocking stimuli should attract more attention than a neutral one, distracting the attention from the temporal information and, therefore, leading to a shorter temporal reproduction. Similar problems concern the so-called TSE (Temporal subjective expansion) effect, described by Tse et al. (2004). In different experiments they showed that when a series of stimuli having the same objective duration are shown in succession, the low-probability oddball stimulus in the series tends to last subjectively longer than the high-probability stimuli. Tse and colleagues attributed the lengthened subjective duration to the engagement of attention and its influence on the amount of perceptual information processed and provided some empirical data in support of this hypothesis. We can conclude, along with Marchetti (2009), that in many situations the subject's prospective duration judgments do not follow the homogeneous and consistent pattern predicted by the attentional-based models.

The major problems, nevertheless, go beyond the particular predictions of this model. The apparently simple statement that attention is allocated to temporal information requires a definition of 'temporal information,' with the risk of resorting to the concept of time as a thing, that exists by itself, to which it is possible to allocate attention like any other physical object. When this problem has been avoided by claiming that the attention is directed to a process (the process underlying temporal experience) instead of a 'thing,' it has been done by referring to the internal clock model, with all the criticisms that this model involves (Block, 2003).

## 3.5 Conclusions

In light of this brief review, we can say that the recent landscape of cognitive models of duration is dominated by two different proposals: the memory change models and the internal clock models (with or without attentional-gate). The former are used especially to explain retrospective duration judgment, in which subjects are not advised in advance that they will be asked to make a duration estimation; the latter to explain prospective duration judgments, in which, before the target temporal interval is shown, subjects are advised that they have to provide a duration estimate. In reverse, the memory-change models reveal themselves inadequate to explain the prospective judgments, because the predictions based on these models are punctually unfulfilled in case of prospective tasks (e.g. in prospective judgment, usually, the more information that is processed, the shorter the estimated duration; see for example Block & Zakay, 1997). Similarly, the internal clock models are inadequate to explain retrospective duration judgments for which the internal 'stopwatch' has not been started at the beginning of the temporal interval to be timed (because timing was not requested) and because the influence of attention seems not to follow the predictions of the model (in this case the criticism is restricted to the attention-gate model; see for example Marchetti 2009).

This mutual exclusivity has pushed different authors to suggest that different processes subserve duration judgments in the two paradigms. We tend to accept this conclusion, if only because of the golden rule according to which if two things seems to be different it is better to treat them as different until proved otherwise (Vicario, 2005). Nevertheless, we also think that considering which characteristics those two mechanisms share could be extremely informative about more general aspects of human temporal knowledge.

It is clear that a model for *remembered durations* should focus on memory and take into account non-temporal features that can somehow influence the process of remembering, before, during and after the actual experience of the event that the subject will retrieve. The basic intuition is still the one exposed by William James that "the length in retrospect depends obviously on the multitudinousness of the memories which the time affords" (James, 1890, p 624). The general criticisms that can be leveled against these models, as remarked before, are those suggested by Vicario (2005) and Block (1990): human memory probably works in very different way than a computer's memory, and the explanations of these models tend to be circular, in the sense that there is not an independent measure of the 'number of changes' (to recall Aristotle) that take place in the cognitive context and that should influence duration retrieval. The only way to measure the influence of these changes is the remembered duration, and vice-versa. Moreover, what is the nature of the change (internal, external, or both)? Can duration be estimated without some sort of change? Who measures the number of changes? These are bigger questions that have been waiting for an answer for more than two thousand years.

Nevertheless, these models, and the studies that they inspired, have contributed to identify many of the factors that can influence duration judgments, often with sound and replicable results. It is possible that when psychologists and neuroscientists reach a better understanding of how memory works, this understanding will be important for determining the mechanisms that underlie the subjective variation of remembered duration. Moreover, these models provide an important alternative to internal clock models, which are a way of explaining the experience of duration that we consider much more problematic. A critical analysis of these models and some reflections over the problem of duration and duration judgment will begin the next chapter.

As Block pointed out more than one time (Block, 1990; 2003), the typical finding at the basis of internal clock models is that, in some animals (namely rats and pigeons), the psychophysical function relating physical duration and psychological duration is approximately linear. This linear relation, such that the increasing of the elapsed physical time corresponds a proportional increasing of the estimated psychological time, has been taken as evidence of the existence of a neurological (or more generally biological) pulse generator (or pacemaker) that produce pulses at a fairly constant rate. This pacemaker, whose pulses are stored in working memory and occasionally compared to other duration-values stored in long-term memory, is considered to be the mechanism that makes animal time-related behavior possible. The scalar property of duration estimation, another classic finding of animal time-related research, has been found to hold also in similar experiments performed with humans, as well as the linear psychophysical relation between subjective and physical time. The conclusion that biological evolution has provided different animals (humans included) with a similar device, mechanism, or organ to perceive or measure duration, seems for many an acceptable conclusion.

We have already review some of the criticisms that has been leveled against the internal clock models (e.g. not taking into account the influence that different activities have on duration estimation; the failure to find the neural basis of the internal clock; the uncontrolled proliferation of clocks related to different behaviors). But these models appear to be problematic in many different ways, especially when applied to human timing behavior. For example, the linear relation between the duration measured by a mechanical clock (inappropriately called ‘physical time’) and the subjective measure of duration cannot be taken for granted. For example, Staddon & Higa (1999), presenting their *multiple-time-scale (MTS) model of habituation*, suggested that psychological duration is a logarithmic function of physical duration; Eisler (1976), quoted by Block (2003), reported instead that psychological time is a power function of physical time, with an exponent of about 0.9. More important, the scalar property of human timing behaviors is not widely supported. The scalar property seems not to hold when very short durations are timed, when timing tasks varying in difficulty are compared, when classical timing tasks are employed (like temporal reproduction), and in situations where highly practised observers exhibited unusual patterns of variance (Wearden & Lejeune, 2007). Wearden and Lejeune tried to reconcile these and other violations with the original SET model, but they admitted that only a partial reconciliation is possible. Moreover, as Staddon & Higa (1999) suggested (referring to animal behavioral studies) the original scalar expectancy theory fails to explain some basic properties of operant behavior on interval-timing procedures (see Staddon & Higa 1999 for more details) and can only accommodate a number of discrepancies by modifications and elaborations that make the theory highly redundant and almost unfalsifiable. This is probably more true for animal behavioral studies, where the data set and the behavioral complexity is relatively limited; nevertheless we agree with Staddon & Higa (1999) that, in any case, a theory more resistant to disproof does not always coincide with a better theory.

Apart from these specific criticisms about the predictions of the model, more general concerns can be addressed.

Some authors (e.g. Buhusi & Meck, 2005; ;Bueti & Walsh, 2010), for example, highlighted the apparently evident fact (evident because nobody is concerned with providing any argument that supports it) that the animal timing capacity, the capacity to estimate temporal intervals with a certain accuracy, is an important biological resource. We think that the reason is not clear. As already noted by Block "it is really difficult to imagine situation in which non human animals have to make various kinds of temporal judgment" (Block, 2003, p. 44). Indeed, it seems hard to study judgment of duration, or more generally any time-related behavior in more ecological situations. Animals follow physiological circadian rhythms, and, in a domestic environment, they could be surprisingly consistent in asking for food at the same hour every day or in performing any other regular behavior. They can somehow calculate which is the right moment to perform an action based on external and internal contingencies, like the velocity of a prey or the strength of their muscles. But we cannot think of any case in which they have to compare two non-simultaneous events and decide if they have the same duration or not, or consider the duration of a temporal interval for any other reason. It is plausible that a particular physiological or neurological rhythm can become a referent to perform motor activities in the correct succession of phases, and to hold the duration of the phases constant (more or less like singing a rhythmical song during repetitive activity to augment productivity). And we can also understand that some of these rhythms can become useful to perform temporal bisection or temporal generalization tasks in a skinner box. But is that enough to call it a 'clock'? And not just because we would probably be referring to a multitude of clocks, but also because, as suggested by Vicario (2005), a clock does not tell the time, it just limits itself to perform a fairly constant activity. We attribute to the clock the capacity to measure the duration, but as already suggested by Aristotle, we need a mind to measure the time. Without jumping into arguments concerning consciousness and its nature, at least for the moment, we know that the task of 'reading the time,' in the internal clock models, is performed by a comparator that reads and compares some kind of 'values' stored in the accumulator[52] and in the reference memory. What exactly the comparator compares is still unclear (Staddon & Higa, 1999), but, the point that we want to make here is that having a rhythm, or following a rhythm, is different than 'reading the time' (see Vicario, 2005 for a similar point of view). You do not need someone that 'counts' in order to follow a rhythm. Can the behavior performed by animals in the temporal bisection and generalization tasks be explained without positing a comparator of successive temporal magnitudes, someone or something that 'reads the time'? And considering that such a behavior is never required in the natural environment, has the internal clock developed under evolutionary pressure for surviving in a skinner box?[53] It seems unlikely.

Returning to the problems connected to the human application of the internal clock models, Block asked the apparently trivial question: "why humans' duration

[52] It is worth remembering here that, as noted by Staddon & Higa, (1999), the accumulator assumption is itself problematic, because it implies a biological process that can increase without limit.

[53] Another hypothesis is that duration comparison is subserved by the same mechanism used to compare other kinds of magnitudes (size, brightness, loudness, etc.). We will consider such a hypothesis in the second part of this thesis.

judgments are sometimes so inaccurate, especially for an organism that is said to possess an internal clock?” (Block, 1990, p. 18). This inaccuracy can indeed be explained referring to the limits of human memory and the other sources of variability (i.e. the switch) taken into account by the model. Nevertheless, the metaphor of the internal clock loses some of its evolutionary appeal if the mechanism doesn’t adequately fulfill the function it has been selected for. Another similar, but we think more compelling question can be asked: if people have an internal clock, why do they not use it? In tasks of reproduction or comparison of different duration usually subjects estimate the duration by counting or performing other kinds of activity. Some of these activities are reported in Franceschini (1998) who debriefed her subjects after a task of duration reproduction. Some of the subjects, while listening the target sound, imagined stripes of light that they used as unit of measurement for the reproduction; some others based their estimation of the process of respiration; others silently produced one or more words during the experience of the temporal interval and repeated it during the reproduction; some of them imagined and reproduced a chant, or performed a ‘grumbling’; others observed the wall in front of them and drew an imaginary line; etc.

We are not aware of other studies that investigated the techniques of time-keeping used by the subjects of this kind of experiments, but according to Zakay (1990) counting strategies seem to be frequent. The question is, why an organism that possess an internal stopwatch with a pacemaker that pulses at a rate of, say 200 cps (Geissler, 1987) prefers to time duration by drawing imaginary lines on the wall or counting at a much lower rate? Maybe because such a stopwatch doesn’t exist: not only animals, but also humans do not encounter many occasions in real life where they have to count (prospectively) the duration of something, and when they have to do so they refer to external repetitive movements such as a clock, a pendulum or the movement of the stars. Why did Galileo use a fairly inaccurate pendulum for his experiment if he was provided a 200cps pacemaker and an internal clock?

The last comment is close to a *reductio ad absurdum*, but the point is this one: it seems that humans use different strategies to estimate durations, and they consist in comparing an activity with another activity, as it is for any kind of measure of duration, which is always a comparison of events (see previous chapter). It is possible that in some cases, like for the estimation of very short temporal intervals, the activity can be referable to some physiological rhythm that works as a pacemaker, but it is just a possibility that, moreover, is more limited than what is suggested by the internal clock models, even if it is true. Probably, such strategies as counting or drawing imaginary lines cannot be performed by the rats and pigeons used in behavioral experiments on timing capacity, but, even if we accept that those animals base their temporal estimation on the activity of an internal clock (and this cannot be taken for granted), the hypothesis that humans should use a similar model for their timing activities seems to be based more on an evolutionary prejudice than on scientific evidence.

Zakay has written that:

> "A methodological problem is the possibility that acquired strategies, like counting […] could prevent the manifestation of temporal experience predicted by the models of duration evaluation" (Zakay, 1990, p. 77)

Vicario (2005) labeled this position as 'curious'. He writes:

> "In altre parole ci sarebbero dei meccanismi di base che assicurano la conversione del tempo fisico in tempo soggettivo, esattamente come ci sono dei meccanismi che assicurano la conversione delle radiazioni elettromagnetiche in colori, delle onde di pressione in suoni, delle sostanze chimiche in odori e sapori eccetera, e di tali meccanismi siamo in grado di elaborare dei modelli. Ma le strategie acquisite come il contare stravolgerebbero il funzionamento dei meccanismi, impedendo la verifica di quei modelli […] Se le esperienze temporali di cui si parla, cioè le valutazioni di durata, non si verificano, la colpa è di strategie come il contare, e non di modelli la cui unica giustificazione è il pregiudizio che il tempo sia uno stimolo, trattabile in salsa neurofisiologica e computazionale"[54] (Vicario, 2005, p. 172)

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[54] "In other words, there should exist some basic mechanisms that assure the conversion of physical time into subjective time, exactly like the mechanisms that assure the conversion of electromagnetic radiation into colors, of pressure waves into sounds, of chemical substances into smells and flavors, etc., and we are able to elaborate models of these mechanisms. But, acquired strategies, like counting, would impair the functioning of these mechanisms, and would prevent us from testing the models […] If the temporal experience of which we are talking about, the judgments of duration, don't take place, it is the fault of strategies like counting, and not of models whose only justification is the preconception that time is a stimulus, that can be handled in neurophysiologic and computational dressing. "

This is probably the epistemological mistake that is still at the basis of the internal clock models, and it is a (scientifically) dangerous presupposition because it is often left implicit. This is the same presupposition criticized by Ornstein (1969) forty years ago in reviewing the idea of the biological clock: the metaphysical belief that time exists by itself, as a natural kind, and human and animals are equipped by a special sensory organ to perceive it.

According to this view, animals, humans included, are certainly able to engage in genuine sensation of duration, spontaneous and automatic like the sensation of cold, or the perception of fragrances. A genuine sensation of duration permitted by the organ of time sense, an internal clock evolved in order to survive in a world where time is everywhere. And this sensation of duration can be distorted by the human subjective mind. We think that this metaphysical view is wrong. There is not a genuine sensation of duration, because there is nothing to be sensitive to. As noted by Vicario (2005) this is just a re-proposition of the old Helmholtzian model, according to which neural processes reflect physical reality, but then past experiences, expectation and reasoning deform everything. Cognitive machinery reflects physical time very well in the nervous system of rats and pigeons, showing linear relationships and scalar properties; the same relations can be shown in the human cognitive machinery if other disturbing factors (like counting) don't intervene. We could think that both rats and humans in a temporal reproduction task are measuring the same *thing*, namely 'duration,' and only this point of view can justify ignoring all the evidence suggesting that they are performing a quite different activity.

The problem of how the human mind can build up a concept of time and duration, or which are the cognitive mechanisms that subserve the expression of what we can call time-related behavior it is not an easy one. The attempt to explain the basic aspects of temporal experience, such as the experience of duration, by positing the existence of an organ dedicated to duration experience, as we can describe the organ of olfactory, is simple, straightforward, but plausibly wrong. It is like explaining the experience of love positing and organ for love, and time is probably more similar to love, than olfaction. Taking into account the difficulty of the problem, we suggest that the science of cognition should abandon the common-sense position that time is a natural kind, and that our temporal experiences are a reflex of this physical time. The next chapter will provide arguments to support this view.

# 4. Epistemological notes

> ogni scienza sarebbe superflua se il modo di apparire delle cose e la loro vera essenza coincidessero
>
> *Karl Marx*

In this chapter we will provide evidences from studies in psychology and cognitive science to support the theoretical and epistemological position that has been sporadically explicitated in the previous reviews, namely that psychological time it is not a (more or less faithful) copy of the physical time. Afterwards, more general epistemological reflections upon the positivistic approach to the mind, its implications and alternatives, will introduce us to the theoretical proposal on the basis of which the present thesis provides his contribute to the study of the portion of human knowledge that we usually call *temporal*.

## 4.1 Physical and psychological time

As noted by Vicario (1998), most part of the psychology of time is based both on the assumption that physical time exists, and the practice to confront the phenomena of the psychological time with the phenomena of the physical time. Perceived time is conventionally assumed to mirror objective time (Eagleman&Pariyadath, 2009; Eagleman, 2008) even if often this assumption is not explicit in the different models proposed by psychologists and cognitive scientists. Nevertheless we think that this assumptions, although implicit, is clear: *a)* as a mechanical clock can measure physical time with the repetitive movement of its hands, an internal biological or neural clock can measure the same physical time (what else?) with the repetitive pulses of a peacemaker stored in an accumulator (Treisman, 1963; Gibbon, Church & Meck, 1984); *b)* in this models the linear relation between the measure of duration given by the internal clock (psychological time) and the measure of duration given by an external clock (often confused with the physical time) is taken as evidence of the goodness of the model (Block, 2003; Wearden, 2005; Gibbon, Church & Meck, 1984); *c)* this linearity can be *distort* by attentional processes, depending on how much attention is allocated on (physical) time, and how much on other aspect of the internal and external reality (Zakay & Block, 1997); *d)* artificial activities like counting can interfere with the activity of our genuine cognitive process for time perception, a device that we evolved like others animals in order to survive in a world where time is everywhere (and at anytime?) (Zakay, 1990); *e)* events that succeed each other in the physical world, have corresponding events that succeed each other in our brain, which produce the 'same' succession in the mental events, which are copied or surrogates (images) of the real events; *f)* time is irreversible in our world as it is in our subjective experience; and the list could continue.

In chapter 2 we have seen how the existence of an absolute time, which flows homogeneous independent of the observers, and that can be taken as a frame of reference to explain subjective temporal phenomena, is quite problematic. It could be interesting to remark how not even in physic exists a clear definition of what we call 'physical time'. Just to give a picture: time has extension but not direction in mechanics, and has direction but not extension in thermodynamics. It is continuous in mechanics and thermodynamics but discontinuous in quantum physic. Time is a fundamental parameter in a world composed by *strings* and can be ignored on a world organized by *loops* (Vicario, 1998; Rovelli, 2010; Giannetto, 1998).

We are not saying that any progress in understanding the ontology or the nature of time in physical terms cannot be of any help for cognitive sciences, but we should consider also the fact that the physical theories on the nature of time do not take in the minimal account the characteristics of the psychological experience of it. Quite the opposite, the more recent conclusions in that field are drawing pictures the more and more counterintuitive and far from our understanding, until questioning the very existence of time (Rovelli, 2010). And for the most, even between psychologists, the physical non-existence is non-existence *tout court*. We think that, if we want to study the mind, and its functioning, we should trying to explain the phenomenology of our temporal experience, in all its complexity, and not try to reduce it to the abstract and fuzzy notion of the absolute time. Indeed, against the dominating folk point of view, the only time to which we can have direct experience is the psychological time, because we can never observe directly the physical time, which is only a useful assumption good to describe natural fact at a macroscopic level. Physical time is an assumption, not the result of an observation. We have already talk in chapter two about the relativity of the concept of time, and how the measure of duration it is always and indirect measure, it is 'just' a relation between actions. Nevertheless, an anecdote can be better of many philosophical analysis to make this point. A very nice, although false, legend (see Rovelli, 2010) says that Galileo discovered that the oscillations of a pendulum have all the same duration by observing a chandelier in the cathedral of Pisa. At Galileo's times an instrument to measure accurately brief temporal interval didn't exist, and this discovery represented a priceless technical advance for the rising scientific method. The legend tells that Galileo made this discovery during a religious function. The scientist was observing the slow oscillation of the giant chandelier and, at the same time, measured the beats of his wrist. With great excitement he noted that the same number of beats occurred within each oscillation, and he arrived to assume that all the oscillations have the same duration. Now, the question is, how did Galileo know that his wrist beats had all the same duration? He didn't know, he assumed it. In fact, some years after Galileo the doctors started to use a clock (which is a sort of pendulum) to control if the wrist beats of their patients have the same duration. We use the wrist beat to control that the pendulum oscillations are regular, then we use the pendulum oscillation to control if the wrist beats are regular. That's what is called a tautology.

What all this means is that we *never* measure time itself, but always physical variables (beats, oscillations, changes of state, etc.), and we always confront one variable with the other (Rovelli, 2010). This arises the possibility that the only 'real' time that we can directly exerience is the psychological time, moreover, as already noted by Vicario, "it is not subjective time which represents physical reality, but is physical time which represents the time of direct experience" (Vicario, 1998, p. 64). In psychology ad psychophysics the opposite is often presupposed:

> "The path is similar to that which leads from the evident differences in quality between colors to the uniformity of electromagnetic radiations that generate the colors. It is the different wavelengths which in some way "represent" our different chromatic sensations, not the colors which '"represent" those differences in wavelength; it is the colors which are the real fact, and their referral to a supposed physical reality is nothing but an abstraction. In other words, we make use of colors to discover wavelengths, not make use of wavelengths to discover colors. To

go back to our main concern, if I have temporal experiences which cannot be represented in time of mechanics (for example, the impression of non-simuitaneity connected to that of non-succession) [see later in the text], I will not speak of "illusion", but I will simply say that the time of mechanics does not suit my aim." (Vicario, 1998, p.64)

After having reframed this theoretical framework, we'll provide some empirical data who will help to understand in a more 'practical' way why it is inconvenient to force the psychological time into the conceptual scheme of the physical time.

### 4.1.1 Succession and simultaneity

It is well known that the order of succession of percepts not always corresponds to the order in which the stimuli are presented to the subject. This kind of temporal illusions, as are often called (Eagleman, 2008; VanWassenhofe, 2009) are known from the beginning of the last century. For example Wundt (1902), studying the accuracy of simultaneity judgments across visual and auditory modality, asked to the participants to indicate the exact position of a hand rotating in a clock-face when a bell rang. In most of the cases the participants indicated a position before the actual point or after the actual point. Wundt called *negative dislocation* the case in which the bell was heard before the right point, and *positive dislocation* the case in which the bell was heard after the right point. But those are not the only documented phenomena of dislocation: sometime a physical simultaneity can be perceived as a succession, in other cases two stimuli in physical succession can be perceived as simultaneous (See Vicario 2005, p. 105). The phenomenon has been classically explained referring to the different speed of sensations, that is usually higher for the auditory domain (Exner, 1975), or the allocation of attention, that directed to a certain stimulus, speeds up its processing (Wundt, 1902). Vicario (1963) studying a similar phenomenon of dislocation within sensory modality ran out these two possible explanations. In one study, three sounds of equal duration (100 ms), were presented in the sequence a1 – b – a2. 'a1' and 'a2' were high tones, 'b' was a low tone. Asked about what they heard the subjects reported the succession A1-A2-B, with the low tone dislocated at the end of the sequence. The higher was the difference in frequency between the high and the low tones, the more often the dislocation was reported. Being the stimuli all auditory, the explanation related to the speed of sensation was discarded. Moreover, subjects to whom was asked to pay particular attention on the middle tone reported more or less the same number of dislocation as the subjects who did not received any particular instruction. According to this observation also the explanation related to attention allocation was considered unlikely (Vicario, 1963; 1998). The explanation provided by Vicario (1963; 1998; 2005) is similar to the one proposed by Benussi (1913) at the beginning of the last century, and remind to the spirit of the gestalt psychology. In brief, the different events are disposed in succession according to a criterion of 'similarity', which is similar to the principle of organization described by Wertheimer in the visual modality. Basically, a non-temporal characteristic, like similarity, has effect on a temporal aspect like succession.

The point here it isn't weather or not Vicario is right, but considering how his analysis can be placed on a different explanatory level compared to the theories which involve sensorial processes or attention allocation:

"We must understand the logic underlying the two aforementioned explanations, namely that of velocity of sensations, and that of attention. That logic presupposes a strict correspondence between physical time and psychological time […], and if some discrepancy is noted between the sequence of stimuli and the succession of perceived events, *the compensation must be found in the physical time of physiological processes,* either by calling upon the ascertained difference in latency of the receptors, or upon the supposed "facilitation" given to processes exalted by a favourable attentional setting. […] But if the imagined compensation on the axis of physical time does not proved to be occurred, one must reconsider the point of departure, that is the strict correspondence between physical and psychological time." (Vicario, 1998)

What is fundamental to grasp in this analysis, is that in the classical explanation a variation in psychological time is explained by the variation in physical time, which is not anymore the physical time of the stimuli/events, but the physical time concerning the physiological, neural processing. The point is that psychological time may not correspond to the physical time of the events, but should correspond to the physical time in the brain. In this way the correspondence between physical and psychological time is safe.

This particular example refers to the phenomenon of temporal succession, but a similar analysis can be done for the phenomena of duration dilation and compression that we have considered before and we will consider extensively later in this thesis. Models that try to explain phenomena of duration dilation (or compression) by a speeding up (or slowing down) of an internal clock are still explain psychological time with physical time, implicitly holding the principle of a strict correspondence between the two. In that case, again, the rate of the biological clock can be different from the rate of the mechanical clock in the lab, but the experienced, psychological time correspond to the physical time (rate) of a physiological process. This doesn't mean that psychological time doesn't depend also on brain processes (see for example Eagleman, 2008 and Marchetti, 2009 for suitable alternatives), but just that it doesn't correspond to the physical time in which these processes take place. An assumption that is implicit in most of the cognitive models that we have reviewed till now.

Going back to Vicario's explanation of the phenomena of dislocations, it seems that not only the non-temporal characteristics of the stimuli affect the order in which the stimuli are perceived, but also:

> "We can perceive a definite order in the elements of a succession only when the qualitative relations between the elements of that succession make it possible for a perceptual structure characterized by duration to come out; if, on the contrary, such relations do not allow the structure to appear, the order of succession will itself not to be clearly defined." (ibid. p. 67)

The difference between a clear impression of succession and an incomprehensible temporal relation is well shown in series of experiment by Vicario (1998; 2005). Imagine to insert a short white sound (50 ms) a) between a long sound and a short sound; b) between two relatively long sounds (i.e. 1 sec). In the first case we would have a classic positive dislocation, with the white sound reported to be after the two other sounds, which are heard without break between them. In the second case, something interesting happens. According to Vicario participants hear very well the two long sounds, but the impulse of white noise doesn't have a precise collocation: "is heard to float in a sort of 'elsewhere' which makes an exact (better, convincing) temporal collocation difficult" (Vicario, 1998, p. 66).

Vicario gives us a more ecological example of unclear temporal relation. If we heard a rapid sequence of notes, in a scale, set for the equal temperament, we easily distinguish each event and put them in a position. For example we can say which note begins the succession and which ends it, even if the events are very short. On the other hand, if the notes are randomly mixed, what we perceive is a confused global event, for which we cannot clearly state how many events there are, how many kinds, which event begins and which event ends the succession (Vicario, 1998). The reason, according to Vicario, is that the quality of the events, in the second case, is too different. Again, the qualitative non-homogeneity of the stimuli (a non temporal aspect), influence the psychological succession of the events (a temporal aspect). The point here, is that in one case a physical succession gives rise to the 'same' psychological succession, and in another case a physical succession gives rise to a confused impression of non-simultaneity, to a *disorder*. In the physical time a non-simultaneity is always an order, but not in the psychological time:

> "The difference lies not in relationships existing in physical time, and surreptitiously extended to psychological time, but in relations emerging from intrinsic properties of the elements (tonal proximity or similarity) which have nothing at all to do with time." (Vicario, 1998, p. 67)

So that in the psychological time we can have relations of *simultaneity* and *non-simultaneity*, with the latter that is different than *succession*; as *non-succession* is different of *simultaneity*. These terms do not make sense if applied to the physical time, which is, we remember, a useful abstraction and not the result of an observation. Moreover, if our experience of succession is grounded on 'similarity' (at least in some cases), a qualitative relationship that is totally different to the temporal relation of the physical events according to the *before* and the *after*, why we should explain one phenomenon reducing, or even only comparing, it to the other?

Another interesting phenomena, similar to the temporal dislocation but much more complex and, somehow, dramatic, is the phenomenon of continuous dilocation (Bozzi & Vicario, 1960; Vicario, 1965; 1998; 2005). Given a succession of sound [a-b-c-d-a-b-c-d-a-b-…], in which *a* and *c* are low tones, and *b* and *d* are high tone, the listener will hear the correspondent (psychological) succession of sound [A-B-C-D-A-B…], at least if each sound has a duration grater than 200ms. When the duration of each sound is drastically reduced (e.g. 50 ms) the subject would get out to the point of hearing two distinct successions, one composed by low tones [A-C-A-C-A..] and the other by high tones [B-D-B-D-B-…]. Vicario explains that the unification occur according to the temporal proximity when the succession is relatively slow, and according to the tonal (qualitative) proximity when the succession is faster. What is dramatic in this study is that the events are discarded by their position in physical time, and perceived as simultaneous with other events that are not simultaneous in physical time. Moreover the temporal interval between two event (say, *a* and *c*), which is another event (*b*) disappear making the event *a* and *c* to be consecutives, and reappears at the same time of the event that in physical time precedes it (*a*). Translated in a bigger order of temporal magnitude, it is like that at midnight of Monday we'll suddenly find ourselves in Wedsnedey, and not in Tuesday; and the action that we perform in Monday-Wednesday will be contemporaneous to the action we perform on Tuesday-Thursday. The same effect can be found in the visual field (Vicario, 1965). This effect constitute an attack to the notion of the correspondence between physical and psychological time even more than the simple effect of dislocation, if not only for the fact that for one physic event (i.e. the sound *a*), two psychological event (*A* and *C*) are perceived. A sort of multiplication of the existent takes place (Vicario, 2005).

As intermediate remark, we should explicit consider a fact that is obvious for everybody. These dramatic effects, which show the lack of correspondence between the 'time of the mind' and the 'time of the world' (and presumably also the time of the physiological processes in the brain, which are of course, "in the world"), take place only within very short durations.

For different temporal scale, the succession of psychological time corresponds to the succession in physical time. This is a fact, but it doesn't create any problem for the point we are making here. We are just showing that under particular condition, the order of succession (at the psychological level) it is not immutable as it is considered to be for the physical time. We should remember that the physical time is a useful abstraction to explain facts in the world and to represent our experience of time: the fact that most of the times physical time and psychological time (better, the relations and characteristic of the events in what we call physical and psychological time) correspond should not surprise us. Otherwise what we call time (always in physical terms) wouldn't be useful anymore! The impression that the order of succession in time is immutable is gained from the observation of an exterminate number of cases in which the inversion of the order lead to different phenomena, events or consequences (Vicario, 2005). Problems arise only from the necessity to find absolutes principle upon which make unobjectionable reasoning. But this necessity doesn't allow us to hypostatize what is just an abstraction (physical time) and transform it in a fact of nature (a natural kind) which is reflected or represented, more or less accurately, in our mind in the process of knowledge. It is possible that it exists here the same distinction between classic and the quantum physic, even though we are not sure it is the right example. As the theory of mechanics is adequate to explain the event in a macroscopic scale (including time), it is not adequate to explain the event in a microscopic scale (including time). Asking which of the two theories is 'real' it doesn't make sense, and trying to reduce one theory to the other is just impossible.

As suggested by Vicario:

> "If we assume that the axiom of the inalterability of the order of succession is derived from the experience, and that the same experience tell us that it is not actually unalterable, we have to accept that the axiom has a limited validity" (Vicario, 2005, p. 139)

It is not the model of the physical time that is wrong (a model itself is never wrong, or false), it is the implicit attempt to explain the phenomenology of psychological time with this model that is wrong. To state the point in a radical way, saying just that 'phenomenological time does not exactly match real time' (see for example Searle, 1992) it is problematic because there is nothing like 'real' time, at least not as a 'chair' or 'electromagnetic radiations' are real. What we can say is that *the immutability of the temporal order it is not a ever-present characteristic of psychological time, as we think it is for what we call 'real', 'physical' or 'objective' time.*

In any case, holding the correspondence between physical and psychological time, considering the phenomena of dislocation as particular cases of distortion, or illusion, that can be explained by the effect of neural processes that happens in a different order compared to the order of the stimuli (but always in physical time); and suggesting that it is this succession that give rise to its psychological, experiential image it is a non justified and arbitrary choice that revealed itself to be problematic. Here we are suggesting an alternative approach according to the simple principle that if two things seem to be different it is advisable to consider them as different, until proved otherwise.

What we are going to try to address now, although briefly, it is exactly the hypothesis that subjective psychological time correspond to the (physical) time of the neural physiological processes (which can be different from the physical time (duration, succession) of external events, of which, however, follows the same rules). Compelling evidences supporting the non-identity between neural and psychological time have been recently masterfully reviewed by Van Wassenhove (2009). We don't have the skills to provide such an educated review, and we'll limit ourselves to describe some studies that can be useful to make the reader understand what we are talking about. The main point can be summarized like this, according to Dennet & Kinsbourne:

> "what matters for the brain is not necessarily when individual representing events happen in various parts of the brain (as long as they happen in time to control the things that need controlling!) but their temporal content" (Dennet & Kinsbourne, 1992)

In other words it is not the temporal latency of the process in the brain, disposed along a linear time, that determine the subjective experience of time, rather it is the content of the information that are processed and the non-temporal characteristics of the neural processes themselves. More or less how it is not the physical temporal aspects of the physical events (e.g. physical order of succession) that 'determine' the psychological time in which these events are experienced, but the qualitative characteristics of the events, and our interaction with them (e.g. similarity).

It is well known that information coming from different perceptual modality are processed in the brain at different speeds. For example, acoustic signals are processed faster than visual signals and, as we have pointed out before, this difference in speed processing was suggested as an explanation for the dislocation effects that take place across modality. The explanation in that case was wrong, but the difference in processing speed is real. For this reason in running race a gun shot is used as signal of departure instead of, say, a flash or any other visual signal. Just because the reaction to an acoustic signal is faster than the reaction to a visual one. Nevertheless, if you snap your finger in front of your face, the sight of your finger and the sound of the snap appear simultaneous, and the same is true for others visual/acoustic simultaneous events. And the same phenomenon takes place within modality, for example in vision, where motion and colour pathways are processed with different latencies, but we can perceive a temporally unified ‘moving red car’. For some reason, the brain (or the mind) synchronizes events that at a physiological level are not synchronic. Again, the psychological time it is not the mirror of the physical time. In this case, of the physical time of our physiological and neurological processes.

In a elegant experiment Stetson and colleagues (Stetson et al. 2006) asked to they subjects to trigger a flash of light by pressing a button. After some trials, they inject a slight delay (e.g. 100 ms) between the button press and the consequent flash. At the beginning the delay was clearly perceived but, after a number of trials the subjects (and their nervous system) showed an adaptation to this delay so that the two events seemed closer in time trial after trial. Then, surprisingly, the flash was showed again right after the button press. The result was that the subjects perceived the flesh of light as occurring before they pressed the button!

One possible explanation of this effect is that the nervous system performs a recalibration of the motor-sensory timing according to the expectation of a particular result from the interaction with the environment. Once again, the ‘before’ and ‘after’ in psychological time depends upon non-temporal aspects like ‘expectations’, and not on the ‘before’ and ‘after’ of the physical time in which physiological processes take place.

### 4.1.2 Duration

The experience of duration, its characteristics and the factors which can influence it, will be largely considered in the second part of this thesis. Here we’ll limit ourselves to a brief review of some phenomena regarding the psychological experience or representation of duration, which provide support for the anti-realistic approach to the study of psychological time. It is well known that the judgment of duration can be easily manipulated (compared to the duration measured by a clock) by many factors:

duration judgments are compressed (with respect to physical duration) during rapid eyes movement called saccades (Morrone et al. 2005); an oddball stimulus in a sequence is usually judged to last longer than the other conventional stimuli (Tse et al. 2004); duration estimation also depends on stimulus complexity or magnitude (Ornstein, 1969; Xuan et al. 2007); the perceptual salience of a stimulus can also lead to dilation and compression of subjective duration: a looming object tend to be judged longer than a stationary object of the same duration in both audition and vision (van Wassenhove et al. 2008).

Talking about *distortion* of the perception of duration (e.g. Cicchini & Morrone, 2009; Eagleman, 2005; Tse et al. 2004;), in cases of *underestimation*, or *overestimation*, both compared to the duration measured by the clock, and the duration for other stimuli (always calculated according to the clock) is, in our opinion, misleading. Especially because it presents again the unfortunate metaphor of the 'sense of time' which considers duration experience to be like a sensory process. The error consists in considering, more or less implicitly, that the size of an object, or its predictability, or its perceptual salience can distort the 'image' of a physical duration as wearing red-colored glasses distorts our perception of color. In both cases the distortion would happen at the level of the physical facts, which are copied as 'already-distorted' in our psychological representations. So, the correspondence between psychological and physical fact is preserved, and the distortion depends on external factors that affect the physical cause, or source, of perception (the electromagnetic waves, or the physical time).

The analogy is as follows: In the case of vision through colored lens, the electromagnetic radiation arrives at the retina, and is processed by the brain as 'already-distorted' (compared to the usual vision) by the lens. The psychological representation of the colors, what we see, is in strict correspondence with the physical source of the colors: psychological reality corresponds to physical reality. In the case of time, some neural machinery, which can be perfectly ascribed to the physical world, is affected by external factors (arousal, size perception, salience). For example, the pacemaker is speeded-up by an arousal augmentation. So the physical rate of the pacemaker is augmented and the successive psychological representation of time is in a strictly correspondence with the physical time (represented by the pacemaker rating, which take place in the physical world).

As the reader probably had noticed, this metaphor seems to work only on the surface. First of all, there is not a sensory organ for time that can receive any distorted signal. In the case of vision the distortion happens outside the body, and physical facts (composition of the lens) affect other physical facts (the electromagnetic radiation). This distortion happens outside of us, it arrives at the retina and is elaborated. But, in the case of duration, the distortion take place inside of us, and there is no distorted signal that 'arrives' or to 'enter in interaction with'; rather, the signal is produced by the brain. The signal is produced 'already-distorted' by the pacemaker, sent to the accumulator, from which we derive our psychological representation of duration. But what does it mean that the signal (time to be perceived) is produced already-distorted? Distorted compared to what?

When we talk about distortion, we usually talk about the same perceptual and psychological process considered in different moments under different conditions: vision of the same objects with or without corrective lenses, for example. People can 'see' the difference between looking through colored lens or not, and easily decide which is the 'normal' and which is the 'distorted' condition on the basis of their past experience viewing the same scene. But people that are judging an oddball stimulus as 'longer in time' have no such relevant experience to compare it to. They cannot say if their duration judgment is distorted for the oddball on the basis of their previous experience because they have never experienced this temporal event before. Until the experimenter tells them that the stimuli have all the same duration, or they check themselves via a mechanical clock, the subjects of this particular experiment cannot say if their perception of time was distorted, or if they had just two different experiences (namely, two different durations). Although there is a way to perceive colors or other visual aspects of the object that we can consider correct according to our past experience of vision of the same or similar objects, there is no way to perceive duration that we can consider correct since we have no past experience of timing the same events. And that because our judgments of duration are abstractions that cannot rely upon any constant interaction between the organism and the external world mediated by a sensory organ such as the eye. Timing a duration it is more like judging the beauty of a painting than distinguish the different colors to which the painting is composed.

Similarly, thinking that there is a clock in the brain to perceive duration it is like thinking that there is a bank in the brain to perceive the value of money. A bill doesn't tell the value if there is nobody that look at it, similarly a clock (or the movement of the stars) doesn't tell the time without someone that 'counts,' at least in Aristotelian terms. Is it enough to recall the specter of the homunculus disguised as an accumulator or a comparator? We do not know, but maybe we should think about it more carefully. Talking about time perception (and distortion) could be an epistemological error.

To conclude, we cannot say that there is a distortion just because under certain conditions some experiences of "the same kind" look different than under other conditions. We do not want to appear too much romantic for the standards of a scientific writing, but, carrying on the metaphor that time is more similar to love than to vision: if we usually experience more love for people that are calm than for people that are violent, should we say that our perception love is distorted by people's temperaments?

Talking about the difference between physical and psychological time we have to go back to the model of the internal clock. Another problem for this model, that we didn't highlight before and it is suitable to the context of this analysis, has been remarked by Van Wassenhove (2009). We know that to explain the differences in temporal latency for different perceptual modality it has been suggested that each sensory modality has its own clock (see for example Wearden et al. 1998). Van Wassenhove writes:

> "With regards to the observed differences in subjective duration of audition and vision, the latency of the auditory switch may be more stable and/or the rate of the auditory pacemaker may be faster than their visual counterparts" (van Wassenhove, 2009, p 1821)

The problem it is that in this perspective it is hard to explain cross-modality modulation of time estimation, for example between audition and vision (van Wassenhove et al. 2008). Basically, the supporters of the internal clock models face the problem to put back together what they have previously divided.

Taking the problem of the unity of time from a different perspective, Eagleman asked himself if time in brain and mind is 'one thing'. Physical time is usually seen as a monolithic aspect of reality, the unique, continuous and infinite flow of time in which everything takes place. On the contrary, psychological time seems to be underpinned by different neural mechanisms that can work both in concert or dissociated (Eagleman, 2008). He gives three example to support his position:

1) Considering Morrone et al. (2005) finding of duration compression around the time of a saccade, if time in the brain it's a unitary phenomenon, one can assume that subjective time in general has been compressed during the saccade? But this is not true, in fact the duration compression does not occur with auditory clicks, but only with flashes (Morrone, 2005; Eagleman, 2005) Therefore, it is not time in general that is compressed, only duration judgments of visual stimuli that are modulated.

2) Similarly, the pitch of an auditory tone, or the rate of a flickering stimulus (which involve temporal judgments) do not change concomitantly with the presentation of an oddball stimuli (for which duration is dilated).

3) Stetson et al. (2008), investigated with a unusual experiment the famous anecdotal report according to which 'time seems to have slowed down' during a life-threatening situation. The hypothesis was that if time, in certain situations, can slow down as a single unified entity (like in the topic scenes of movies, when not only movements but also voices and sounds are slowed down) then the slow motion should entail consequences, such as the ability for higher temporal resolution. The experimenters measured time perception of participants who fell backward from a 50-m tower into a net below. During the fall, they watched a little screen in which images were succeeding rapidly and had to report what they have seen on the screen. If time was really slowing down, participant would have been able to recognize more images during the fall than in a not frightening situations. The results showed that participants retrospectively reported an increased perception of duration for their fall (as compared to others' falls). Nevertheless, they showed no evidence for increased temporal resolution when measured during the 3 s fall. As Ornstein (1969) has already noted, the modulation interested the remembered time, not the experienced time.

According to Eagleman:

"These experiments provide rich evidence that time is not a single entity. Instead, it is probable that a diverse group of neural mechanisms mediates temporal judgments. Note that this framework for thinking about time perception places it in line with the history of vision research, in which it is understood that vision emerges as the collaboration of many subpopulations that code for different aspects of scenes (motion, position, color, and so on) […]. These subpopulations usually work in concert, but they can be separated in the laboratory. In the domain of time perception, it is probable that duration, simultaneity, temporal order, flicker rate, and other judgments are underpinned by different mechanisms that normally concur but are not required to." (Eagleman, 2008, p. 134)

We tend to agree with Eagleman conclusions, even if the comparison with the visual system risk to make return from the window, the metaphor of the 'time sense' that was banished from the door.

What it seems clear, after all, is that psychological time follow different rules, and have different characteristics of the that useful abstraction that we call physical time.

## 4.2 A brief digression about mind and reality

*Delle cose visibili e delle cose invisibili soltanto gli dèi hanno conoscenza certa; gli uomini possono soltanto congetturare.*

Alcmeone

We should ask now, in the light of what we discussed, why many psychologists and cognitive scientists are still continue to believe in a Absolute Newtonian time that exist independently of everything else? And why they think that our experience of time reflects more or less accurately the physical time? We have already given some partial answers here and there on the text (3.5, 4.1). Here, we want to provide a more general explanation of this epistemological attitude considering how the case of time can be ascribed to a more general theory of knowledge according to which our thought works with mental representations of the real objects of the world.

The *epistemological problem* (Von Glasersfeld, 1998 a,b) – how we gain knowledge of the reality and if this knowledge is reliable and 'true' – it is old as the beginning of philosophy. We can assume, with a few exception, that the presuppositions of empirical psychology (cognitive sciences, neurosciences), like for all the other sciences, are 'realistic' (Olivetti Berardinelli, 1986; Bateson, 1972; Von Glasersfeld, 1998a). Usually, scientists, and not only them, share a common and reasonable belief: there is a 'reality' in which the objects that we know and perceive exist independently of our interaction with them. Indeed, just a few of us would say, without any doubt, that if I close my eyes the computer that is in front of me would stop to exist until I will open my eyes again. Similarly, we all have an intuitive answer to the question posed by Berkeley a long time ago: if a three fell in the forest, and nobody ear it, does it make noise?

We can assume that we can experience the external world, and the object and events that constitute the reality, through our senses: we see object and actions, we ear sounds, we taste food, etc. Nevertheless, when we think about a particular object, or the smell of a flower, we wouldn't admit that our thinking is dealing directly with the object itself. Instead, we could say that our thought is dealing with the *idea* of something, its concept or representation. Now, the representation of, say, a 'chair' can be different for different people, and the differences can be more or less marked depending on the culture, the education, the kind and the number of experiences with different chairs, etc. All these factors are usually ascribed to what it is called the subjective sphere of knowledge: the portion of our knowledge that refers to private experience and make each mind different from another. Nevertheless, under some aspects at least, our representation of the chair should be similar to the representation of other people, otherwise it will be impossible to communicate. Usually it is thought that the aspects of a representation, or an idea, that are common between observers derive from the objective characteristics of the object itself, and on the fact that all human share the same perceptual devices which are used to interact and derive information from the outside world. In other words, the result of the perception is a mental image, representation or concept that correspond to the real object in the world. This representation usually has some aspects or characteristics that are idiosyncratic for that particular perceiver, which are part of the so-called *subjective knowledge*; and some other aspects that are the same for all the observers, which are usually called *objective knowledge*. In the end, what we call *truth*, usually correspond to the objective knowledge: the characteristics of the representation that match the characteristic of the object by itself. *Veritas est adaequatio rei et intellectus*, said st. Thomas.

Silvio Ceccato (Ceccato, 1972; Ceccato & Zonta, 1980) among other, has sustained that this kind of theory of knowledge, that we can design with Putnam (1981) as "methaphysical realism", is one of the major error of occidental philosophy. It is in fact impossible to base a theory of knowledge on the comparison between the thing itself and his image in the mind of the subject. As already noted by Socrate (*Teeteto*) it is impossible to engage in a comparison between two things, one external and the other internal to the observer, when only one of these two things it is actually present to the perceiver: the product of his perception. How can we come to know if the two things are between them equal or different? The problem of what Ceccato has called the 'doubling mistake' stands in the necessity of a comparison between a *cognito* and an *incognito* upon which it is impossible to base a theory of knowledge.

In other words, if knowing consists in a description or reproduction of the world *per sè*, we should be sure that the image (representation) that appear in our mind on the basis of our perception and reasoning is under any aspects (or at least some of them) homomorphic to the world itself. But, in order to do so we should be able to compare the representation to what we suppose it represents. But this is impossible, because we cannot transcend the human modality of perception and conceptualization. What it is present to the subject it is only his own experience, and, as already remarked by Kant, the experience can't say anything about the thing itself.

Then, if it is impossible to know the thing by itself and to base our knowledge of the world upon the positive description of its features, which kind of knowledge is left to us? What is the alternative? A possible answer is that all what we can know about the real world is what the world it is not. A metaphor that we borrowed from Watzlawick (1998) can help to introduce the argument.

A captain of a boat, in a dark and stormy night, has to go through a canal not reported on the maps and without the help of a lighthouse or any other facilitation.

Either will pass the canal and gain the open sea, or will crash on the cliffs. If he loses the boat and the life, his defeat proves that the route was the wrong one, we could say that he discovered what the canal *was not*. If, on the other hand, he goes trough the strait successfully, this simply proof that in no point he entered in collision with the structure and the nature (otherwise *incognita*) of the canal. It doesn't tell anything about how close he went to a collision, how safe was the canal, or its topographical conformation. The chosen route was *fitting* to the topography of the canal, but it doesn't mean that the canal and the route correspond. Philosophers and scientists rarely die if they took a wrong route in the formulation of their theories, but they shouldn't interpret the success of they conjectures or experiments as the proof that the reality is well reflected in their way of thinking. As Warren McCulloch suggested: "To have proved a hypothesis false is indeed the peak of knowledge" (McCulloch, 1966).

The epistemological attitude to base our knowledge of the world on negative (it is not like this) instead of positive (it is like this) assumptions should not frighten any scientist. Indeed, on this principle is based the widespread accepted scientific theory of biological evolution through natural selection (See Von Glasersfeld, 1998b). The nature (or, if you want the reality) limits itself to eliminate what it is not *suitable* in that determined moment and place. The organisms are not adapting themselves to a preconstituted reality, but they find different ways to go through it without die. In these terms we are not allowed to make any deduction about the objective nature of a world that manifested itself only for negative effects. As noted by Von Glasersfeld (1998b), the interpretation of natural selection in positive terms is a useless tautology. An external observer of the history of evolution could say that an organism survives because it is the 'fittest' in his own environment (implicitly assuming that there are organisms that are more adapted than others in that environment),[55] but on the other hand he has to admit that the only criterion he has to consider this organism 'fitted' it is because it survived.

What has been said, although partial and anecdotal rather than analytics, could be sufficient to demonstrate that the concept of *correspondence* or *homomorphism*

[55] "For a theory in which surviving is the only criterion of selection of the species, there are only two possibilities: a species if fitted to his environment or not, it dies or survives. Only an external observer who expressly introduces different criteria from the mere survival – for example economy, simplicity, elegance – could, on the basis of this scale of evaluation, talk about a 'better' or 'whorse' fitness" (Von Glasersfeld, 1998, p. 21)

between knowledge and reality, essential for the metaphysical realism, cannot be derived from the concept of 'fitting', and should not be confused with it. For this reason, the simple fact that some organisms (human included), in some cases, are able to perform correctly (according to the clock) in similar temporal tasks (i.e. bisection tasks), and more important, that a certain number of abstract rules are useful to make prediction about the temporal aspects of some physical events, it is not enough to say that these behaviors and representations are based on the characteristics of time *per sè*. This belief only shows that it is taking place a process of *reification* (Salvini, 1998) for which the result of a process (mental operations, abstraction, etc.) is considered as an object independent from the process itself, and become the cause (or the source) of the process. The preeminent influence that the metaphysical realism has on the scientific community can explain, but not justify, the belief according to which our representation of time reflects the physical time.

Therefore, if human knowledge cannot be considered as a simple reflection of the reality, it goes without saying that what we call reality has to be somehow constructed by the organism in the interaction with his environment. It is important to point out that this position do not lead necessarily to a solipsistic theory according to which only the mind has ontological existence and everything else is just the product of the perception. A position well represented by the philosophy of Berkeley according to which '*esse est percipi*'. We are aware that the argument presented in this paragraph and the fast analysis that we provided could suggest that all this it is just a sneaky version of old solipsistics an idealistic positions, but it is not. The questions that we are trying to answer are epistemological and not ontological, we are not interested about the ontology of the objects, or the mind, but about how humans come to have knowledge of all this things. Maintaining a position that we can consider agnostic about the ontological discussion, what we are suggesting it is that the nature and features of what we call mental representations, concepts or images can be better understood highlighting and studying the mental operations upon which our knowledge is actively constructed on the bases of the experience, rather than the (unknowable) characteristics of the object, as part of an independent reality, which should be passively reflected by our senses. Without stressing too much the theoretical basis of an approach that will become more clear through the rest of this thesis, it is important to say that, in general terms, this epistemological approach it is not new in philosophy and science. The list of contributions in this direction is very long: Greek pre-socratic philosophers (Pirrone, IV sec; Senofane, VIII sec; Protagora, V sec); the English empirists (Locke, Hume, Berkeley); the philosophy of Vico ( 1668 -1744); the criticism of Kant (1724-1804); the genetic epistemology by Piaget (1896 - 1980); the Italian Operative School (Ceccato; Vaccarino; Somenzi; Accame,); the American cybernetics (Bateson; VonFoerster; Wiener); the systemic approach (Olivetti Belardinelli, M.); the biology of cognition (Maturana, H.; Varela, F.) the radical constructivism of Ernst Von Glasersfeld (1917 - 2010); the second generation of cognitive science (Lakoff, G.; Johnson, M.). All these approaches share a more or less radical refusal of the metaphysical realism, and disagree between them about the nature of the operation that are involved in construing what we perceive as a reality.

The metaphysical belief in a physical reality that is reflected in our thought is especially misleading for the study of the mental representation of time and temporal knowledge. Persuaded by the apparently ontological solidity of time as a natural kind, and anchored to the metaphysical belief that the mind should somehow reflect the *real* organization of the ‘things-in-the-world’ in order to deal with it in an adapted way, many scientists has just ignored both the dramatic differences between psychological time and physical time, considering them as simple distortions caused by external psychological factors, and the recent discoveries of the relativistic and quantum physics, remaining faithful to a Newtonian representation of time which is considered by many nothing more than an useful abstraction. Therefore, what it was a conceptual construction of the human mind, *physical time*, conceived in order to make good enough predictions at a macroscopic level and developed in order to organize human activities; has become a natural kind, and independent entity, used to explain the conceptual constructions from which it derives. The circularity of this reasoning speaks for the need to find another explanation for the human experience of time. In the next chapter we will introduce an attempt to describe how the thinking mind come to have a concept of time avoiding this realistic approach.

# 5. How do we think about time? A proposal

## 5.1 Abstract concepts and embodied mind

*Only by forgetting this primitive world of metaphor can one live with any repose, security, and consistency: only by means of the petrification and coagulation of a mass of images which originally streamed from the primal faculty of human imagination like a fiery liquid, only in the invincible faith that this sun, this window, this table is a truth in itself, in short, only by forgetting that he himself is an artistically creating subject, does man live with any repose, security, and consistency. If but for an instant he could escape from the prison walls of this faith, his "self consciousness" would be immediately destroyed.*

Friedrich Wilhelm Nietzsche

The proposal that we are going to introduce it is to ascribe to the theoretical school of *cognitive linguistics* and what has been called *the second generation of cognitive sciences* (Lackoff & Johnson, 1999).

We can track back the beginning of cognitive linguistics to the early '70, when some linguists started to move serious criticisms to the dominant paradigms of *generative grammar* (Chomsky, 1957) and *truth-conditional semantics* (Davidson, 1967). According to Croft & Cruse (2004), cognitive linguistics differentiated itself from these paradigms for three central assumptions: language is not an autonomous cognitive faculty; grammar is conceptualizations; and the assumption that linguistic knowledge emerges from language use. In a second moment, important findings in experimental psychology, linguistic anthropology, cognitive modeling and gesture research has been considered together with linguistics findings under the theoretical flag of *embodied cognition* (Lakoff & Johnson, 1999) inaugurating the second generation of cognitive sciences. We are going to remark some important aspects of this theoretical framework before concentrating on the construction of the concept of time.

According to Lakoff and Johnson (1999) the three major findings of cognitive science are: 1) the mind is inherently embodied; 2) thought is mostly unconscious; 3) abstract concepts are largely metaphorical. The concept of *embodied mind* arose in opposition with the traditional point of view of anglo-american analytical philosophy and classic psychology and cognitive science, according to which human reason consists in the manipulation of abstract and conventional symbols, which are in themselves meaningless and become meaningful through the association with object of the real world, or with other symbols.[56] This approach has two kinds of consequences:

1) the faculty of reasoning, at least at a formal level, can be intended as an algorithmic manipulation of symbols which happens independently from their semantic connotation. In other words the mind is seen as a computer software "which derives meaning from taking meaningless symbols as input, manipulating them by rule, and giving meaningless symbols as output" (Lakoff & Johnson, 1999, p. 6). A software that happens to be implemented on the human brain but that, in principle, could work on any other adequate hardware.

2) This sort of approach presuppose the existence of an external reality, with universal and knowable features which become the content (meaning, in case of language) of the mental symbols, or representations, through either innate or arbitrary association. Therefore, as in the metaphysical realism, truth is established through the correspondence theory: there is one truth and it corresponds to the characteristics and relationships between the objects themselves.

We have already seen how this last position is strongly metaphysical because based on the impossible comparison between something that is *cognito* (the perception, representation, sensation) and something that is *incognito* (the thing itself that our concept should represent). Although they arrive to similar conclusions, Lakoff &

[56] The most quoted supporters of this theoretical approach are probably Noam Chomsky (1957) and Jerry Fodor (1975). We are aware that the picture we are drawing here doesn't do justice to the deep and complex analysis of those authors, which can been refuse in toto only from an ideological point of view that we do not want to assume. Here the idea is to stress, maybe radicalizing a bit, the differences between two approaches in order to make as clear as possible the theoretical and epistemological ground on which we want to formulate and verify (or we should say, try to falsify) our hypothesis.

Johnson, in presenting the epistemological basis of embodied cognition seem to make the inverse path compared to the skeptics point of view presented in the last chapter: instead of deny (2) with philosophical and logical arguments, and consequently refuse (1) on this epistemological basis; rather, embodimists refuse (1), mostly on the basis of empirical data from different fields, and thus refuse (2) as a valid epistemological basis to explain these findings.

Embodied cognition contrasts the hypothesis according to which the mind is a kind of abstract computer program which is run on a biological hardware (namely the body and the nervous system), with the latter that can determining nothing about the nature of the program. It suggests instead that concepts and reason strongly depend upon the body, and the way we use it to interact with the world. Therefore the mind cannot be understood independently of the "hardware", but people with different bodies should think significantly in a different way.

In particular, as it was already for Piaget (1926), embodimists stress the role of perceptual and motor system in shaping certain kinds of concepts as spatial-relation concepts, basic-level cathegorization, color concepts and aspectual concepts (Lakoff & Johnson, 1999). Basically the architecture of our brain network, the structure of our sensory organs, the pattern of interaction with the environment are constitutive of our though, in terms of mental representations and the relations between them. The content, the semantics and the modality of our thoughts, as well as the relation between them, are not arbitrary determined by correspondence to the external world, or by internal association of abstract symbols according to abstract rules (most of them innate), but are contingently determined by the structures of the hardware: the structure of neural networks, the modality of perception, the sensory-motor experience and so on. The example of what have been called *basic-level categories* (Rosh et al. 1976) can be useful.

Neural beings must categorize (Lakoff & Johnson, 1999). Not only them – even the ameba roughly categorizes between food and non-food – but organisms provided by a complex nervous system are capable of more complex interactions with the environment and able to create many different categories. The verb 'create' it is not to be intended in a figurative meaning, but in the literal ontological sense (at least to the extend for which ontology and epistemology cannot be separated (Bateson, 1972) ). The realistic perspective according to which the categories derives from a conscious act of categorization according to the similarities of the objects in the world is here refused in advantage of a perspective that consider categories, concepts and experience inseparable (Lakoff & Johnson, 1999). The act of perception it is already an act of categorization, because perception is an action between the body and a non-better specified outside world, which is conditioned by the bodily structures involved. In these terms the concept is "a neural structure that is actually part of, or make use of, the sensory-motor system of our brain." (Lakoff & Johnson, 1999) As we will see later, even abstract concepts could be tracked back to basic sensory-motor experiences. Therefore categorization, especially in its lower sensory-motor level, it is unconscious and our body and brain determine what kind of categories we will have and their structure:

> "We have eyes and hears, arms and legs that work in certain very definite ways and not in others. We have a visual system, with topographic maps and orientation-sensitive cells, that provides structure for our ability to conceptualize spatial relations. Our abilities to move in the way we do and to track the motion of other things give motion a major role in our conceptual system. The fact that we have muscles and use them to apply force in certain ways leads to the structure of our system of causal concepts. What is important it is not just that we have bodies, and that thought is somehow embodied. What is important is that the peculiar nature of our bodies shapes our very possibilities for conceptualization and categorization." (p. 19)

According to Lakoff & Johnson, the reason why some aspects or categories of the world are so stable and universally shared to make it difficult believe they are not dependent on natural characteristic of the world, adequately reflected by our reason, it is because we have evolved one class of categories that optimally fit our bodily experience of entities and certain important differences in the natural environment.[57] This is the

[57] We do not know exactly which is the opinion of Lakoff and Johnson at this regards, but, to our concern, when we say that certain categories optimally *fit* the characteristics of the environment we do not mean that these categories reflect the structure of the reality better than others, but that they have been 'selected' because useful and generalizable across many situations. This kind of (unconscious) knowledge is always a negative-knowledge of the structure of the environment, like a key that can work with many locks without saying nothing about the structure of the locks. All that we know is determined, or better conditioned by the structure of the key!

case of the so-called *basic-level categories* described by Eleanor Rosh and colleagues (Rosh et al., 1976). These categories are usually situated in the middle of a categorical hierarchy according to the power of inclusion, like *chair* in "furniture – chair – rocking chair" or *car* in "vehicle – car – sport car". These middle-categories have a kind of cognitive priority compared to "superordinate" and "subordinate" levels.

This cognitive priority is conditioned by aspect of our bodies, brain and minds and not by aspects of the reality itself. The basic-level is: 1) The highest level at which a single mental image can represent the entire category (e.g. you cannot get a mental image of 'a piece of furniture', in general); 2) It is the highest level at which category member have similarly perceived overall shapes (e.g. What's a shape of a general vehicle?); 3) It is the highest level for which people use similar form of interaction for this category; 4) It is the level at which most of our knowledge is organized.

The cognitive priority of the basic-level categories is constructing unconsciously based on gestalt-perception, motor programs and mental images, which are species-specific and embodied, instead on the external characteristics of the objects themselves, which are anyway impossible to know. For this reason, the basic-level categories are the source of our more stable knowledge, and when our basic-level capacities are extended by scientific instrumentation, we are able to select useful real-world division. This is also why the scientific theories that pertain mostly to this categorical level are the most widely accepted: because they are useful not because they are true. In fact, if a bee cannot clearly recognize the border of a 33 rpm record, on a table we would say that the distinction between the two object 'exists', but the bee cannot see it clearly; on the other hand, if a quantum physicist says us that the distinction between the record ant the table is 'actually' fuzzy and constantly changing, thus indeterminable, should we say that we invented a border that actually do not exists?

Beside these radical thoughts, it appear clear that even if the characteristics of the object might play a role on the process of categorization, this process cannot take place independently of the interaction between our body/brain and the environment, and it is mostly unconscious. To conclude the discussion about basic-level categories we can quote again Lakoff & Johnson:

"Our embodied system of basic-level concepts has evolved to 'fit' the ways in which our bodies, over the course of evolution, have been coupled to our environment, partly for the sake of survival, partly for the sake of human flourishing beyond mere survival, and partly by chance. It is not that every basic-level concept exists because of its survival value, but without such an embodied system coupled to our environment, we would not have survived. The basic level of conceptualization is the cornerstone of embodied realism." (Lakoff & Johnson, 1999, p. 91)

What Lakoff and Jonhson called embodied realism admit the existence of a world independent of our understanding of it, and also that we can have stable knowledge of it. On the other hand it doesn't admit that our concepts and forms of reason are characterized by the external world itself. Instead, our knowledge of the world cannot transcend the way we make experience of it, which in turn is determined to the structure of our bodies. In this sense knowledge is always embodied, based on the structure of our sensory organs, our ability to move and manipulate objects, the detailed structure of our brain, our culture, and our interaction with our environment. A knowledge that we can consider independent to the experience it is just a metaphysical belief, or, using the colorful language of Montaigne: "… au plus élevé trône du monde, si ne sommes assis que sur notre cul". [58]

At this point, a doubt can arise: it is fully understandable how our concepts of spatial relations, colors, or our representations of concrete objects categories could be based on the sensory-motor experience of moving and looking around in the physical environment, on the different activations of color cones in our retina, or on our ability to move and manipulate objects; but what about the concept of things that we cannot see, touch or bodily interact with, like love, freedom, quality etc. How the embodied cognition can explain the construction of the component of knowledge that we call *abstract* on the basis of sensory-motor experience? The answer stands in what Lakoff and Johnson have designed as the third major discovery of cognitive science: *conceptual metaphors*.

If we consider how we talk about abstract concepts and actions in our everyday language we could see how most of our abstract expressions are metaphorical:

[58] "… on the highest throne in the world, we still sit only on our own bottom"

1) Tomorrow is a *big* day

2) I'm feeling *up* today

3) We've been *close* for years, but we are beginning to *drift apart*

4) Prices are *high*

5) They *pushed* the bill *through* Congress

6) I *see* what you mean

7) I've never been able to *grasp* transfinite numbers[59]

In (1) importance is expressed in terms of size, in (2) happiness is expressed in terms of spatial orientation, similarity in terms of proximity in (3), quantity is expressed in terms of vertical orientation (4), in (5) an achieved result is given in terms of exertion of force, in (6) seeing is knowing and in (7) understanding is grasping. According to cognitive linguists (Lakoff & Johnson, 1999; 1980) we not only borrow terms that usually refers to concrete actions (grasping, seeing), or relations between concrete objects (proximity, dimension, spatial location) to talk about abstract relations and subjective experiences (e.g. importance, value, feelings, knowledge); more than that, we use (or better, re-use) the conceptual structure of these concrete domains of the experience to understand and shape our comprehension of abstract conceptual domain, which cannot be based directly on the sensory-motor experience of the world. In these terms a metaphor is not only a linguistic construction, but a very cognitive process which permits to understand a conceptual domain, idea, or experience in terms of another. Lakoff & Johnson distinguished *conceptual metaphors*, which refer to the cognitive process, and *linguistic metaphors*, which refer to the linguistic expressions which design the underlying cognitive process (Lakoff & Johnson, 1980). In fact, according to Lakoff & Johnson (1980; 1999), metaphors are first of all a matter of thought rather than language. Linguistic metaphorical expressions, ultimately, reflect underneath conceptual metaphors whose formation is language independent. For example, if we can use expressions like:

8) Your conclusions are *clear*

[59] Examples from Lakoff & Johnson, 1999, pp. 52-54.

9) Do you *see* what I mean?

10) This is an *opaque* statement

It is because we learn to reason about knowledge in terms of vision, and the cognitive mechanism for such conceptualization is conceptual metaphor, which allows us to use the physical and perceptual logic of *seeing* to reason about *knowledge* and *understanding*. In other words, we talk like this because we have learnt to think like this, and not vice versa. We are going to see very soon how these conceptual metaphors are constructed on the basis of experience. Before we allow ourselves for a short historical digression.

Even though the central role of metaphorical thought in human understanding and reasoning has been popularized relatively recently by the linguist George Lakoff and the philosopher Mark Johnson (Lakoff & Johnson, 1980; 1999), it has been around for quite a long time in the history of thought. As noted by Daniel Casasanto (2005), this idea has been first articulated in the field of linguistics and cognitive science by Jeffery Gruber in his MIT dissertation (Gruber, 1965) in which he presented his Thematic Relation Hypothesis (TRH). Jackendoff (1983) wrote about it in these terms:

> "The psychological claim behind [Gruber's linguistic discovery] is that the mind does not manufacture abstract concepts out of thin air...it adapts machinery that is already there, both in the development of the individual organism and in the evolutionary development of the species. (1983, pg. 188-9)"

A similar suggestion is presented by Pinker:

> "Suppose ancestral circuits for reasoning about space and force were copied, the copies' connections to the eyes and muscles were severed, and references to the physical world were bleached out. The circuits could serve as a scaffolding whose slots are filled with symbols for more abstract concerns like states, possessions, ideas, and desires. (pg. 355)"

The basic idea here (especially for Pinker) is that our capacity of thinking in abstract terms is the result of a process of cognitive *exactation* occurred through the biological evolution of the human kind, and now innate (Pinker, 1997; but see also

Srinivasan & Carey, 2010). According to Pinker humans are not actually making analogies (consciously or unconsciously) when they use (what cognitive linguists call) *conceptual metaphors*, but they are using 'dead metaphors': "as when we talk of breakfast without thinking of it as breaking a fast" (ibid. p. 356). The concept of *exactation* is borrowed from the work of evolutionary biologist Steven Jay Gould and paleontologist Elisabeth Vrba (1982). They suggested that a character, previously shaped by natural selection for a particular function, is coopted for a new use. A popular example is the one of feathers, originally evolved to regulate body temperature in small dinosaurs, and only later co-opted for flight (Gould, 1991).

Julian Jaynes (1976) who anticipated the contemporaneous debate about metaphor and thought studying the methaphorical structure of abstract thinking and it's changes through the history of humanity, expressed caution in drawing easy parallel between the biological evolution of organic features and the evolution (Biological? Cultural?) of cognitive capacities as if abstract thinking could evolve from object manipulation abilities as the cetacean flipper evolved from an ancestral paw (Jaynes, 1976). We will go back on this discussion several times in this thesis.

Nevertheless, even before than psychologists and cognitive scientists made their appearance on the heart, philosophers have considered the importance of metaphors for human reason. This paragraph reports as epigraph the quotation of a young Nietzsche when, just over twenty, wrote: "We believe that we know something about the things themselves when we speak of trees, colors, snow, and flowers; and yet we possess nothing but metaphors for things — metaphors which correspond in no way to the original entities." (Nietzsche, 1873, p. 4). According to Nietzsche concepts born for the necessity of equalize what it is not equal. He suggests the example of the leaves of trees, for which it doesn't exist one that is the same of the other but they are unified in the category of 'leaf'. The concept of leaf is, according to Nietzsche, the product of the metaphor, which pushes together what is far apart, and makes similar what is different. And, in good syntony with the anti-realistic epistemological position described above, he suggests that it is by mean of these concepts, generated by "arbitrarily discarding these individual differences" (Nietzsche, 1873, p. 4). that we built-up what we call reality, and in the oblivion of this rather arbitrary construction we deceive ourselves in believing that we can know the truth:

"What then is truth? A movable host of metaphors, metonymies, and; anthropomorphisms: in short, a sum of human relations which have been poetically and rhetorically intensified, transferred, and embellished, and which, after long usage, seem to a people to be fixed, canonical, and binding. Truths are illusions which we have forgotten are illusions- they are metaphors that have become worn out and have been drained of sensuous force, coins which have lost their embossing and are now considered as metal and no longer as coins. (Nietzsche, 1873, p. 5)."

Before Nietzsche, also for Giambattista Vico, at the beginning of the XVIII century, metaphor has the power to give sense to what has no sense, and it had an important rule in the evolution of human thought (Vico, 1744/1948). In the attempt, that he himself defined *heroic*, to reconstruct the first steps of human beings toward reflection and reason, Vico individuated in the metaphorical thinking the key of the evolution of knowledge. It is thanks to the power of metaphors to create connections and make similar what is different that the crash of a thunder became the voice of a tempered god and that the sky became anthropomorphically animated giving origin to the religions. In Vico, metaphor was a cognitive act, with an important heuristic value (Battistini, 2005) for the 'poetic logic' (Vico, 1744/1948) that the first men used in order to make sense of world:

"All the first tropes are corollaries of this poetic logic. The most luminous and therefore the most necessary and frequent is metaphor. It is most praised when it gives sense and passion to insensate things, in accordance with the metaphysics above discussed, by which the first poets attributed to bodies the being of animate substances, with capacities measured by their own, namely sense and passion, and in this way made fables of them. Thus every metaphor so formed is a fable in brief. This gives a basis for judging the time when metaphors made their appearance in the languages. All the metaphors conveyed by likenesses taken from bodies to signify the operations of abstract minds must date from times when philosophies were taking shape. The proof of this is that in every language the terms needed for the refined arts and recondite sciences are of rustic origin." (Vico, 1744/1948, p. 116 )

Moreover, even the epistemological approach presented by Vico in *De Antiquissima Italorum Sapientia* appear to be very close to the embodied realism:

"Allo stesso modo in cui la verità divina è ciò che dio conosce, nel momento in cui la crea e la compone, la verità umana è ciò che l'uomo conosce costruendolo con le sue azioni e formandolo attraverso di esse. Perciò la scienza (scientia) è conoscenza (cogito) del nascere, del modo in cui sono state prodotte le cose"[60] (quoted. in Von Glasersfeld, 1998b)

As Vico use to say: *verum ipsum factum* – truth is what has been done.

Back to the contemporaneous contributions[61] of cognitive science, according to Lakoff & Johnson, conceptual metaphors are pervasive both in thought and language, and it is very hard to think about an abstract domain of subjective experience that it is not organized in terms of metaphor. But are these metaphors dead, as Pinker suggested, or we are actually reasoning in analogical and metaphorical terms when thinking to abstract conceptual domains? How is it learned? What is the mechanism by which we reason metaphorically?

Reasoning through conceptual metaphors consists in understanding a domain of experience by mean of a different domain of experience. The metaphor theory describes a *Target domain*, usually abstract, and a *Source domain*, usually more concrete. Some of the conceptual relations that characterize the source domain (e.g. the experience of 'grasping'), which are derived directly from the sensory-motor processes that take place during the interaction with the environment, are transferred (mapping) to the target domain (e.g. the subjective experience of 'understanding'), so that the latter can be understood in terms of the former. Thanks to this metaphorical process we can built-up a complex and stable knowledge of abstract concepts and subjective experiences in spite of the lack of sensorial basis. In other words, what cannot be seen, heard or touch is understood and represented in our mind *as if* it can be seen, heard or touch.

According to Lakoff & Johnson (1980, 1999), the metaphorical expressions that in language are used to designate abstract domains reflects the underneath conceptual organization, but don't determine it. Metaphors are a matter of though before than

[60] "In the same way that the truth of God is what God knows, when he creates and composes it, the human truth is what man knows building it with his own action and giving it form through them. So science (scientia) is knowledge (cogito) of birth, the way things have been produced." (our transaltion).

[61] Others, more recent significant contributions that here we can just mention are those of Paul Lafargue (The origin of abstract ideas, 1898/1906), and Hans Blumenberg (Paradigmen zu einer Metaphorologie, 1960).

language, and the conceptual mapping from the concrete to the abstract takes place on the basis of the sensory-motor and perceptual experience. The theory of conflation, proposed by Johnson (Lakoff & Johnson, 1999) sketch out a possible learning mechanisms for this conceptual mapping:

> "For young children, subjective (non-sensorimotor) experiences and judgments, on the one hand, and sensorimotor experiences, on the other, are so regularly conflated – undifferentiated in experience – that for a time children do not distinguish between the two when they occur together. For example, for an infant, the subjective experience of affection is typically correlated with the sensory experience of warmth, the warmth of being held. During the period of conflation, associations are automatically built up between the two domains. Later, during a period of differentiation, children are then able to separate out the domains, but the cross-domain associations persist. These persisting associations are the mappings of conceptual metaphor that will lead the same infant, later in life, to speak of a 'a warm smile,' 'a big problem,' and 'a close friend.' ". (Lakoff & Johnson, 1999, p. 47)

The mechanism of conflation refers to what Lakoff & Johnson (1980; 1999) have called primary conceptual metaphors, for which the source and the target domain are often experienced together in the everyday life: things that are close in space are usually similar (similarity is proximity); feeling happy usually correspond to a upright posture (happy is up); getting information usually correspond to seeing (knowing is seeing); etc. Primary metaphors are supposed to be universal because arise from conflation of subjective feelings and experience, and sensory-motor and perceptual interaction that are shared across human beings:

> "Universal early experiences lead to universal conflations, which then develop into universal (or widespread) conventional conceptual metaphors" (Lakoff & Johnson, 1999, p. 46)

Secondary, or complex, conceptual metaphors are instead conceptual mapping which are a combination of primary metaphors. Complex metaphors form a huge part of our conceptual system and are well represented in our everyday language. Some examples are:

1) *Love is a journey*:

- Our relationship has hit a *dead-end street*
- The relationships is *going anywhere*
- We are *spinning our wheels*
- The marriage is *on the rocks*

2)Argument is war:

- Your claims are *indefensible*.
- He attacked every *weak point* in my argument.
- His criticisms were *right on target*.
- I *demolished* his argument.

Clearly, the mechanisms of conflation cannot be applied to these conceptual metaphors. In any case, we are going to focus our attention on the so-called 'primary metaphors,' in which we found the basic temporal metaphors. But, are these metaphors dead or alive? In the next chapter we are going to analyze the metaphorical construction of the temporal conceptual domain from more concrete conceptual domain as *space* and *motion*. Thus, we will offer evidence, all across this thesis that the metaphorical mapping that link time and space is alive and active in our conceptual system, and not only a neurological phylogenetic vestigial. However, to conclude we want to point out, without considering it extensively, that in the last years many evidences which falsify the 'death metaphor' theory have been produced: Daniel Casasanto ad colleagues has provided evidences for the psychological effectiveness of conceptual metaphors like 'similarity is proximity' (Casasanto, 2008a), right is good/left is bad (Casasanto, 2009; Casasanto & Jasmin, 2010; Wilhems et al. 2010); up is good/down is bad (Casasanto & Dijkstra, 2010); Albritton et al. (1992), for the conceptual metaphors "love is a physical force"; and the list could continue.

## 5.2 Time and space

The reasoning could be more or less like this, and it seems quite straightforward: abstract concepts are mostly metaphorical, the concept of time is an abstract concept, therefore the concept of time is metaphorical.

The first question is foregone: is time (and temporal reasoning) an abstract domain as knowledge, valence, happiness or freedom? Isn't time something that we can directly perceive like colors, and interact with like physical object in space? We do not think so. Even if part of the psychological studies that has been done treated time as a matter of perception more or less like vision or touch, it doesn't mean it is the correct way. There is nothing like a 'time sense' nor a particular organ predisposed to it (Fraisse, 1963; Ornstein, 1969) and psychological time is not the copy of an external physical time (e.g. Vicario, 2005, 1998; Marchetti, 2009; Edelman, 2008).

According to Lakoff & Johnson (1999) time is not conceptualized in his own terms, but rather is conceptualized in significant part metaphorically and metonymically:

> "We cannot observe time itself – if time even exists as a thing-in-itself. We can only observe events and compare them. In the world, there are iterative events against which other events are compared. We define time by metonymy: successive iterations of a type of event stand for intervals of 'time'" (Lakoff & Johnson, 1999, p. 138)

As Gibson already pointed out: "Event are perceivable, time is not" (Gibson, 1975). The metonymical process consists in taking the 'literal' characteristics of our perception of events and let them stand for what we call 'time'. According to Lakoff and Johnson, therefore, time has a direction and is irreversible because events are directional and irreversible (most of the time!); Time is continuous because we experience events as continuous; time can be divided because most of the events has a beginning and a end; and finally, time can be measured because iterations of events can be counted. Therefore, what is 'literal', or at least non metaphorical in our conception of time, is characterized by the comparison of events. Does it mean that we do not have an experience of time? Lakoff and Johnson did not use this radical terms:

> "What it means is that our real experience of time is always relative to our real experience of events. It also means that our experience of time is dependent on our embodied conceptualization of time in terms of events. This is a major point: Experience does not always come prior to conceptualization, because conceptualization is itself embodied. Further, it means

that our experience of time is grounded in other experiences, the experiences of events." (ibid. p. 139)

We will go back to this issues later. Now we can continue noticing that our experience, or conceptualization, of time it is more complex than that. Not only time has a direction, but the events that happen in time have a *position*, and they can be *before* or *after* each other and before or after me (But one event cannot be both before and after me!); not only time is continuous, but is constantly *moving*; not only time is divisible, but *bigger* event can *contain* other events, which can *contain* other events and so on; and in time not only we can count the number of events, but we can measure each event and compare their durations, saying if one event is *longer* than the other. Very little, maybe nothing, of this understanding of time is purely temporal: we use a number of metaphors to conceptualize time in this way, and each metaphor comes with his own conceptual metaphysics (Lakoff & Johnson, 1999). The principal metaphorical sources of our temporal reasoning are: spatial orientation, movement in space, and physical extension.

Although we cannot touch or see time, we talk about it as if we could (Lakoff & Johnson, 1980, 1999; Casasanto & Boroditsky, 2008; Boroditsky, 2000; Clark, 1973; Jackendoff, 1983;): We can *move* meeting *forward* as we can literally move a car forward on the street, we can *waste* time as we waste money and we can *look behind* to our past as we can literally look behind our back. As it should be clear now, these metaphorical expression are not just linguistic frippery, but are like a window on the structure of our conceptual system. The claim is that we think about time in terms of (movement, orientation and extension in) space, and this thesis want to provide a contribution to the developing and testing of this hypothesis.

One of the basic metaphors for psychological time is the orientational one (Lakoff & Johnson, 1999; Clark, 1973). In English, as in many other languages, the future is in front of the observer, and the past is behind him. Common linguistic expressions for this conceptual mapping are:

1) That's all *behind* us now
2) Let's out that in *back of* us

3) We are looking *ahead to* the future

4) He has a great future *in front of* him

Front/back temporal metaphor in language are often accompanied by congruent gestures (Lakoff & Johnson, 1999), according to which we point backward for yesterday and forward for tomorrow. Nùñez and Sweetser (2006) have provided evidences that when the metaphorical mapping in language is reversed, like in the Aymara language, in which future is behind and past is ahead,[62] also the correspondent gesture for future or past events are reversed.

Although the front/back temporal metaphor is widespread in many languages, we do not know about any linguistic usage of a horizontal left/right schema. The reason, could be, as proposed by Clark (1973), that being 'left' and 'right' symmetrical, this spatial schema do not fit with the characteristic of events succession, which is asymmetrical in respect to the present moment. Nevertheless, the left-right temporal orientation is present in gestures, and the passage of time assumes a different orientation (i.e. left-to-right/right-to-left) across different culture (Casasanto & Jasmin, 2010). Moreover, beyond gesture, a cospicuos part of our representation of time seems to rely on this horizontal spatial schema (Ouellet, et al. in press, Weger & Pratt, 2008), even if it is not adequately represented in language. We will investigate this topic in deep in the 3rd part of this thesis.

The time orientation metaphor has space as a source domain but it says nothing about motion. The observer can be stationary or moving. Movement (in space) is another source domain for the metaphorical construction of time. This assertion has one important implication that could not to be evident at a first look. If movement is the source and time is the target domain, it means that at a conceptual and perceptual (which cannot always be distinguished in the embodied cognition theory) motion appear to be primary in relation to time. In other words, motion, in our basic conceptualizations, is not understood in the same way as in Newtonian physics, where

[62] For example: 'Past time' in Aymara is *mayra pacha*, where '*mayra*' stand for 'eye', 'sight' or 'front', and '*pacha*' stands for 'time'. How this metaphorical pattern could emerge it is not clear. It has been proposed that, since Aymara put strong emphasis on the visual perception as a source of knowledge (i.e. it has to be grammatically specified), and since the past can be known/seen, but not the future, the past is located in front of the observer (where it can be seen) and the future behind (where it cannot be seen). For more details see Nùñez and Sweetser, 2006.

time is a more basic concept and motion is defined as the change of location over time. Here is time that is understood in terms of motion. Nevertheless, this conclusion should not surprise us. We have seen that the Newtonian absolute time as physical entity is only a useful abstraction, and that time can be measured only as a relation between two events, which can be two motions. Therefore, not only in our conceptual system, but also in the scientific understanding and measurement of physical events, motion seems to be primary in comparison to time. Indeed, if we cannot perceive time directly, we can instead perceive motion and there is an area or our brain, in the visual system, which is dedicated to the detection of motion. Hesse et al. (1989) documented the case of a patient who was unable to perceive motion[63] after a damage in that area (posterior temporal cortex, V5). Such an area for the global perception of time has not been found, and we have good reason to belief that it doesn't exist (see Chap. 3 and 4) Moreover, in a following section, we will see how motion is conceptually primary compared to time also in the ontogenetic development (5.2.3).

For the moment, let's consider these sentences:

5) The deadline is *approaching* us
6) Time *comes* and *goes*
7) We are *getting close* to Christmas
8) We are *coming up* on Friday

In all these cases, our relationship with events in the future is represented in terms of motion. More precisely, we can distinguish two different motion-schemas: in 5) and 6) an event (the deadline) or time itself is moving, but in 7) and 8) the observer is moving, 'getting close' or 'coming up' on a particular event. These two different metaphorical linguistic schemas has been called the Time-moving and the Ego-moving schema (Boroditsky, 2000; Lakof & Johnson, 1999; Clark, 1973; Mc Taggart, 1908).

In the time moving schema, an observer is stationary and facing in a fixed direction. The future is in front of him and the past is behind of him. Time is represented by a series of events that are moving past the observer from front to back

[63] Specificlly, for speed higher than 10°/sec the patient was unable to recognize both the direction and the velocity of the movement. Ability that was however compromized for lower speeds. The deficit was selective for visual motion.

(from the future to the past). Moreover, the ‘front’ of each event is the one in the direction of motion. Following this schema events are moving, and the direction of the movement is toward the past (and toward the observer).

In the time moving schema, the observer is moving facing the future in front of him, and leaving the past behind him. The events are stationary point on a metaphorical path that are passed one after the other by the moving observer. Following this schema, therefore, the observer is moving (and not the events) and the direction of the movement is toward the future. In the two schemas the direction of the movement is therefore opposite, as exemplified by the figure 5.

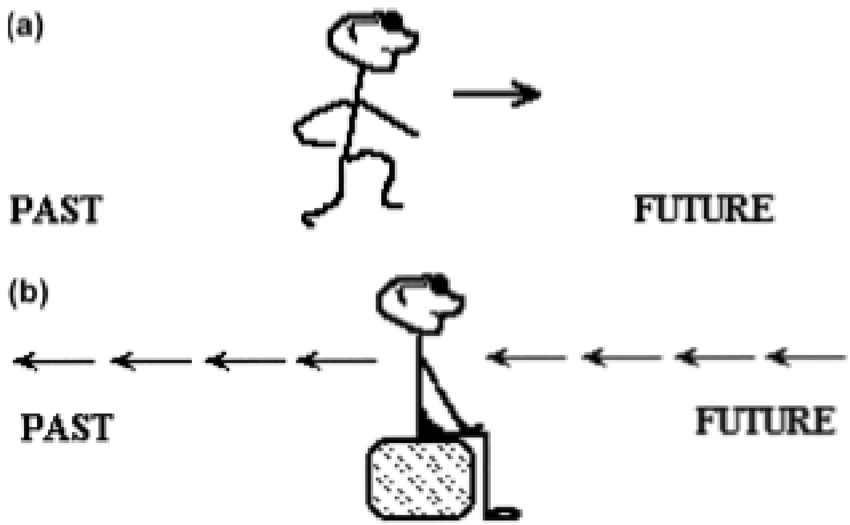


Fig 5: (From Boroditsky, 2000).

These two different temporal schemas have been already described at the beginning of the last century by the English philosopher John Ellis mcTaggart:

“If the events are taken as moving by a fixed point of presentness, the movement is from future to past, since the future events are those which have not yet passed the point, and the past are those which have. If presentness is taken as a moving point successively related to each of a series of events, the movement is from past to future. Thus we say that events come out of the future, but we say that we ourselves move towards the future” (Mc Taggart, 1908)

These two schemas of time, conceptualized in terms of motion and well represented in our everyday language, are rather different. To some extent they are also incompatible, because the direction of motion is reversed if compared to each other. In one case, the event are moving from the future to the past, in the other case the observer is moving from the past to the future. On the other hand, both ego-moving and time-moving schema can be paired with the time Orientation Metaphor, in which the observer is at the present, the future is *ahead* and the past is *behind*.

These conventional metaphorical mapping can be used to produce or understand novel metaphorical expressions, and this speaks for their active rule in the conceptual system. Novel metaphorical expression can be understood instantaneously if they activate a conventional metaphorical mapping such as the ego-moving or time-moving schema:

9) The precious seconds *oozed* through my fingers.
10) The deadline *sneaked by* me.
11) The deadline was *marching* toward me like a brass band
12) The days *cascaded* by.[64]

These are not conventional ways to talk about the passage of time, but we do not have any difficulty in understanding what they mean. According to Lakoff & Johnson this happens because a substantial part of the understanding mechanism consists in the activation of an already existing stable correspondence between concepts across different domains. In this case, between the conceptual domains of TIME and MOTION.

The conceptual domains of TIME and MOTION are coupled, at first, through the mechanism of conflation (Lakoff & Johnson, 1999), which take place in the numerous situations which the time and the motion domain comes together in experience:

"Every day we take part in 'motion-situation' – that is, we move relative to others and others move relative to us. We automatically correlate that motion (whether by us or by others)

[64] Examples from Lakoff & Johnson, 1999, p. 149.

with those events that provide us with our sense of time, what we call 'time-defining events': our bodily rhythms, the movements of clocks, and so on. In short we correlate time defining events with motion, either by us or by others. For example we correlate distance traveled with duration. Thus, in a motion situation, motion is correlated with time-defining events." (Lakoff & Johnson, 1999, p. 151)

Similarly, when we walk down the street future encounters are in front of us, and we are approaching them (ego-moving), and if to object are traveling toward us (at the same speed) the one that is closer to us will arrive before the other, and so on. In these particular experience, when the conflation is possible, the relation between the source and the target domain is metonymical and symmetric. It means that since motion in space and time (in terms of time-defining events) are present together as parts of a whole, one can stand metonymically for the other. For example duration can stand metonymically for distance: "Milano is 5 hours from Roma"; and distance can stand metonymically for duration: "I slept for 80 km in the train". Similarly, walking down on a dark street you can tell to your friend "I do not know what's up ahead of us", referring to a spatial location which is correlated, presented together, with the time in which you will reach the spatial location. Therefore, according to Lakoff and Johnson (1999), the Time Orientation, Time-moving and Ego-moving metaphors, are not arbitrary, but are motivated by our basic everyday experience and they should be universally widespread. We will discuss on the universality of the ego-moving and time-moving schemas in the last part of this thesis.

Not only movement and orientation in space, but also the characteristics and the relationships between the material objects in space are a good source of metaphorical mapping for our conceptual construction of the domain of time. For example, in the ego-moving metaphorical schema, time is conceived like a path, on the ground, on which the observer can move over. Through this particular mapping time receive an extension, like all the other object in space, and this extension can be measured and divided in parts. Hence an amount of time can be 'long' or 'short'; a certain duration can be 'divided' arbitrarily in smaller durations; bigger temporal intervals can 'contain' smaller temporal intervals as bigger objects can contain smaller objects; etc. Consider these examples:

13) Will you be staying a *long* time or a *short* time?

14) What will be the *length* of his visit?

15) Let's spread the conference *over* two weeks.

16) She arrived *on* Monday.

17) He'll have his degree *within* two years.

18) We'll arrive *in* the summer.

19) The meeting is *at* noon.

In (13) and (14) temporal interval has an extension that can be quantified in unidimensional length; in (15) and (16) time is like a surface, where we can arrive 'on', or we can spread an activity 'over'; in (17) and (18) time is a container 'in' which event take place; and so on. All these expressions, that at a first look don't even seem metaphorical, reflect the different modality in which characteristics and relations of the spatial conceptual domain are used to shape the abstract conceptual domain of time. The possibility of a complex temporal reasoning is based also on the human capacity to conceive temporal intervals as container, durations as distances, events as surfaces, and so on.

### 5.2.1 Phylogenetical and ontogenetical evidences

What we have seen until now has an important implication: space (in terms of orientation, movement, extension) is a more basic portion of experience than time (duration, succession, direction). This is quite in contrast with the mainstream of the philosophical and scientific thinking. For the Greek philosophers that we considered, Plato and Aristotle, for which space had an ontological (but not epistemological) primacy compared to time and movement, as it was already for Parmenides (see chapter 2). Nevertheless, when the philosopher started thinking about the characteristics and structure of human knowledge, space and time has often been compared in equal terms. They were mutual interaction for Locke, and they become the two *a priori* conditions of knowledge for Kant. Even for Bergson, which emphasized the scientific and rational spatialization of time, there is a 'true duration' which is independent of space and constitute our inner, primitive and conscious conception of time. But the most important in these terms (especially for psychology and cognitive science, which seem to be highly influenced by the law of classic mechanics (Vicario, 2005, 1998)) is still the Newtonian theory, which postulates an absolute time and an absolute space, independent from each other and from everything else. From the relation between these two basic parameters we can get the parameters of acceleration and velocity, which we use to describe motion.

We have suggested, instead, that space and motion are the concrete sources upon which is based our temporal reasoning. Showing once again how psychological time doesn't follow the same rules of physical time (as we usually understand it). In this section we will provide evidences for the priority of space and movement relative to time, showing how the latter depends on the former, in language and thought, through phylogeny and ontogeny.

### 5.2.2 Semantic changes throughout history

Semantic changes throughout history confirm the priority of the spatial. Most of the temporal terms that we currently use (across different languages) have a spatial etymology, and throughout history many spatial terms become temporal, but rarely occurred the opposite (Sweetser, 1990).

The word *tempus*, which gave rise to the English *time*, the French *temps*, the Italian *tempo*, etc., meant 'time' in classical Latin. Yet in earlier Latin, it meant a 'space marked off', and referred to divisions of the sky (Allen, 1880):

> The word [tempus] referred originally to space; the meaning ' time' is later, and came about in this way: the quarters of the heavens are thought of as corresponding to and standing for the parts of the day and year; east is morning, south noon, and so on. (Allen, 1880, pg. 140).

Going further back on time, the word Tempus derives from the Greek Τέμνω [*Temno*], which means "to divide", which in turn can be tracked-down till the Proto-indoeuropean root **da*: 'to divide, to take apart' (Pokorny, 2007; Gebser, 1949/1985). From this root was formed the Greek verb *daio*, which meant "to divide, to lay apart, to lacerate" in the Ionian dialect, the Sanskrit *dayate* "he devides", and the German word for "part" or "share", *Teil*. This root is also at the basis of the word *demonic* (Gebser, 1949/1985). Even the word "time" is based on a clear spatial etymology.

Many other temporal terms have a clear spatial derivation. For example the word *year*[65] originally meant "that which makes [a complete cycle]," and from verbal root *ei- meaning "to do, make." (On-line etymological dictionary). From a similar meaning derives the temporal word period, from the Greek *peri-* “around” and *hodos* “a going, way, journey”.

Before (from P.Gmc. **bi-* "by" + **forana* "from the front,") and after (OE *aeftan,* “behind”) have clear spatial origins and are still used as spatial terms (Partridge, 1958). When the origin of a temporal word cannot be find in spatial orientation terms, often it derives from terms that characterize movements. For example the English “late”, derives from the PIE base *lad- "slow, weary".[66]

These are just a few examples, but it is enough to consult a good etymological dictionary to appreciate the spatial root of most of the temporal world in many languages.

### 5.2.3 Language acquisition and child development

In general, children spontaneously use spatial terms earlier than their temporal counterparts (see H. Clark, 1973, for review). For example, young children use the word *in* according to its spatial meaning (e.g., *in the box*) far more than they use it in temporal meanings (e.g., *in a minute*), even though temporal uses of *in* are common in adult speech (H. Clark, 1973). Moreover, children use locative expressions like *here* and *there* before they use temporal expression like *now* and *then*. They produce *where* questions earlier than *when* questions, and sometimes misinterpret *when* as *where.* Eve Clark reports that when to young children were asked questions like “*When* did the boy jump over the fence?” they sometimes gave locative answers (e.g., “right there”). According to Clark (1973) “these locative answer to temporal questions are consistent with the notion that time expressions are based on a spatial metaphor acquired after

[65] O.E. gear (W.Saxon), ger (Anglian) "year," from P.Gmc. *jæram "year" (cf. O.S., O.H.G. jar, O.N. ar, Dan. aar, O.Fris. ger, Du. jaar, Ger. Jahr, Goth. jer "year"), from PIE *yer-o-, from base *yer-/*yor- "year, season" (cf. Avestan yare (nom. sing.) "year;" Gk. hora "year, season, any part of a year," also "any part of a day, hour;" O.C.S. jaru, Boh. jaro "spring;" L. hornus "of this year;" O.Pers. dušiyaram "famine," lit. "bad year".

[66] cf. O.N. latr "sluggish, lazy," M.Du., O.S. lat, Ger. laß "idle, weary," Goth. lats "weary, sluggish, lazy," latjan "to hinder"

spatial terms are acquired, and therefore, time expressions will at first misinterpreted as spatial expressions” (p. 59).

Beyond language acquisition, also Jean Piaget (1927/1969) sustained the idea that space and velocity, which can be grasped intuitively, are primary in respect to time, which has to be constructed operationally, in the development of the child:

> “To the adult, who is used to measurements and steeped in the ideas of classical mechanics, distance and time are the primitive concepts from which velocity must be derived: v=s/t. But we might equally hold – and observation of children […] support this belief which, moreover, agrees with the finding of quantum mechanics – that the primitive concepts are, in fact, distance and velocity and that it is time which is gradually derived from them…” (Piaget, 1927/69 pp. 39-40)

According to Piaget “we cannot perceive time as such since, unlike space or velocity, it does not impinge upon our senses. All we can perceive is events, i.e. motions, actions, speeds, and their results” (ibid. p. 268). A child, asked to judge the duration of the activity of drawing strokes on a paper, will judge the duration according to the result of the activity, the more strokes are drawn the more time it has taken.[67] Similarly, a child watching a character moving on a linear path will say that the character reached B after A, and C after B, and he might also say that the character took longer to go from A to C than from A to B. But in this case temporal succession coincide with the spatial, and durations with the displacements, so that the child can give the correct answer by relying on purely spatial considerations. But if we ask the child to compare two characters, who go from A to C but with different velocity, he will be quite unable to  tell us which of the two characters reach its destination first, because pure spatial considerations are no longer enough to give the correct answer (Piaget, 1927; but see also Casasanto et al. 2010 and chapter __ of this thesis). For children at this stage of development time is just confused (or fused) with space (or velocity, power or results of an actions, etc. which are all perceptible aspects of events).

[67] If the child is asked to draw strokes and stopped after 15 sec, and after he’s asked to draw again strokes on another paper, but faster, and stopped again after 15 seconds, he will judge the second activity as longer compared to the first, because more strokes has been drawn. Moreover he will come to the anti-Newtonian conclusion that more speed corresponds to more time.

According to Piaget we cannot grasp temporal reasoning without having grasped *reversible operations*, that leads to the paradoxical conclusion that we can understand and reasoning about an irreversible and homogeneous flux of time only when we become able to reverse the flux of time in our mind, when we can follow it in either directions:

> "To follow time along the simple and irreversible course of events is simply to live it without taking cognizance of it. To know it, on the other hand, is to retrace it in either direction. Rational time is therefore reversible, whereas empirical time is irreversible, and the former cannot embrace the latter unless this fundamental contrast is fully taken into account" (ibid. p. 259)

According to Piaget the idea of time involves the co-ordinations of at least two motion, namely the simultaneous ordination of the states produced during the two motions, i.e. "When Jack was in A Luke was in B, and when Luke was in C Jack was in C too". But in order to appreciate the simultaneities of two independent movements, and compare their orders, the child should be able to: 1) group together different moments that are not simultaneous (A, B, C, etc.), considering them simultaneously like different points in space; hold the asymmetry of succession between two terms (If B comes after A than A comes before B) but presuppose that duration, which is the interval between two successive terms, is a symmetrical relation between these terms: the duration (interval) AB is identical with the duration (interval) BA, and any event occurring between A and B must necessarily occur between B and A (exactly like the path between two point on a line in space is the same, or have the same content and extension, as the reverse path).

Piaget theory about the construction of the concept of time in the child is highly complex, and we will get back to it later in this work (see 12.1). Yet, even given this convergent evidence from patterns of language change through history, language acquisition, language use and conceptual development it would still be imprudent to conclude that space is especially important for *thinking* about time in a grown-up mind that has already grasp the reversible operations. In the next session, we'll provide evidences that the mapping from space to time is psychologically relevant beyond language and when our concept of time is completely formed.

### 5.2.4 Current psychological evidences

We can anticipate that there are, at the moment, a good amount of evidences that support the metaphor theory. Evidence which support the hypothesis that space-time *mapping* correspond to an active psychological process which underlies temporal reasoning, and challenge the skeptical view that see it as a sort of etymological relic without any psychological effect. As noted by Daniel Casasanto (2009a) "time has become for the metaphor theorist what the fruit fly is for the geneticist", namely the favorite testbed for the metaphorical mechanisms that are supposed to take place during abstract reasoning. Since the studies presented in the 2$^{nd}$, 3$^{rd}$, and 4$^{th}$ part of this work are part of this field of research, and the relevant literature will be reviewed extensively across this thesis, we'll limit ourselves to give here some introductory evidences which, however, should be enough to persuade somebody that, at least in certain cases, we use space to think about time.

Concerning the orientational metaphor according to which future is in front of us and past is behind, a recent experiment provides good evidence for the activity of this spatial mapping during temporal reasoning, or, more specifically for this case, during mental time travels. Miles and colleagues (2010a) asked to their participants either to recall what their everyday life circumstances had been like 4 years before, or to imagine what their everyday life circumstances might be like 4 years in the future. Participants were wearing a blindfold, and were fitted with a movement sensor, attached to the lateral part of the left leg immediately above the knee. The results of the experiment showed that, when participants where thinking about the past slightly leaned backwards, and when they were thinking about the future they leaned forward. Basically the physical movement corresponded to the metaphorical direction of time, according to which future is in front and past is behind. According to the authors, the ability to 'travel' subjectively through time "appears to be grounded in the perception-action systems that support social-cognitive functioning. In this way, the embodiment of time and space yields an overt behavioral marker of an otherwise invisible mental operation" (Miles et al, 2010a, p. 223).

Substantial evidences for the spatial basis of our temporal thinking come from studies about the Ego-moving and Time-moving schema. Do we actually think about time using one or both of these schemas? Does using one or the other make any difference? Are these schemas grounded in spatial reasoning or are they just temporal?

To find it out, a series of experiments have been designed (McGlone and Harding, 1998; Boroditsky, 2000; Boroditsky & Ramscar, 2002). Experiments that all involve an ambiguous question:

"*Next Wednesday's meeting has been moved forward two days. So, to which day has the meeting been rescheduled?*"

This is an ambiguous question because the answer can be both *Monday* and *Friday*. Lakoff & Johnson (1999) suggested that the response depends on which kind of schema the person is using to reason about time and event succession. In the Time-moving metaphor, future events are moving toward the observer, which is in the present. Thus, if the meeting is a future event, it will be moved forward in the direction of the movement, therefore closer to the present, on Monday (Fig. 6a). On the other hand, in the Ego-moving metaphor, in which the observer is moving toward the future, the meeting will be moved forward following the direction of the movement, than farther away from the observer, on Friday (Fig. 6b).

A

B

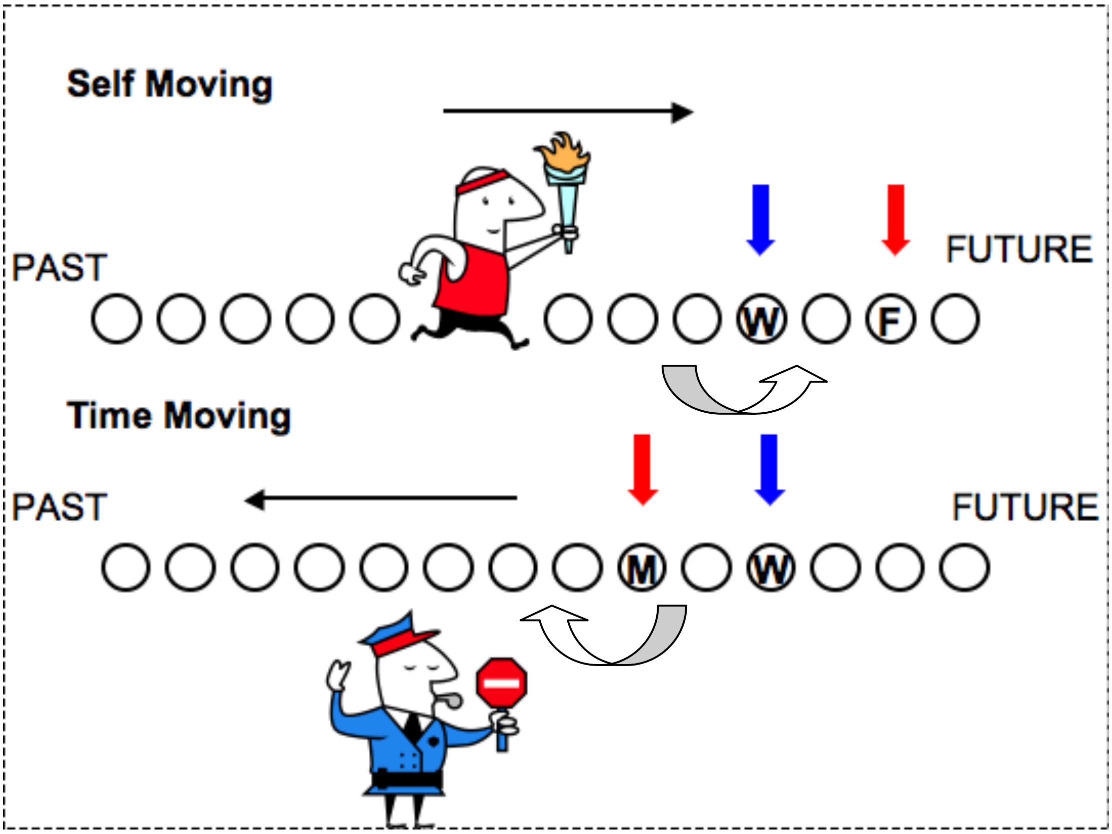


Fig. 6

To test if the two temporal schemas correspond to different cognitive procedures, McGlone & Hardling (1998) designed an experiment in which their subjects had to fill up a short questionnaire which contained questions about days of the week. Questions which required a temporal reasoning.  There where two version of this questionnaire. In one version the questions were phrased according to the “Time-Moving Metaphor”, e.g. “*the deadline passed* two days ago. In which day was the deadline?” Subjects have to respond with the correct day of the week. On the other version, the questions were phrased according to the “Self-moving Metaphor”, for example “*We passed the deadline* two days ago”, and they had still to indicate in which day was the deadline.

In both cases the answer is the same, because these questions are not ambiguous. Only the way how the question are phrased is different. But, after that participants went through a bunch questions like this, an ambiguous question like the ‘Wednesday meeting question’ was presented.

Results show that the subjects that were 'trained' in using the "time-moving metaphor" were significantly more likely to answer *Monday*, and the subjects that were 'trained' to use the "Self moving" metaphor were significantly more likely to say *Friday*.

This experiment has provided evidences that ego-moving and time-moving sentences are actually understood through different conceptual schemas, and that we can alternatively use this two different psychological perspectives to represent the succession of the events in time. But, how do we know that these are metaphors, how do we know that behind these temporal schema there are a metaphorical mapping from space to time?

To find out, Lera Boroditsky (Boroditsky, 2000) designed an experiment where, instead of temporal phrases using one schema or another, subjects were primed with spatial information: pictorial and linguistic stimuli that describe spatial references and spatial movement. For one version of the questionnaire pictures and phrases which represent the spatial *Ego-moving* schema, i.e. the picture of a men moving toward a vase of flowers, with the caption "the flower is in front of me" (Fig 7 a). In the other version the questionnaire presented stimuli designed according to the spatial *Object-moving* schema (which is the spatial version of the "Time-moving schema", even though, following metaphor theory, we should say that the "time-moving" is the temporal version of the "object-moving", because space is the source domain: events metaphorically move in time like the object literally move in space). An example of object-moving schema, consisted in a static character facing a hat box and a Kleenex box coming toward him, with the caption: "The hat box is in front of the Kleenex" (Fig 7 b).

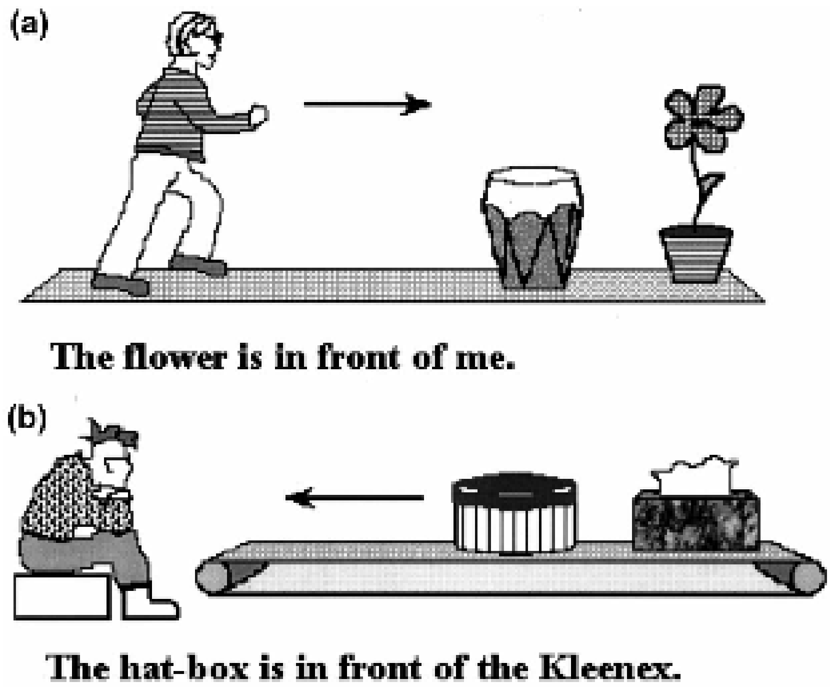


Fig. 7: (From Boroditsky, 2000)

For both the version of the questionnaire, at the end, the 'Wednesday meeting question' was asked.

The reasoning behind this experiment is this one: if these temporal schemas are built up metaphorically on more concrete spatial schemas, than spatial information, that in this case are irrelevant for temporal reasoning, will instead influence the temporal judgment. And that's indeed what happened: subjects primed with the Ego-moving spatial schema were more likely (73%) to use the correspondent temporal schema, saying that the meeting has been moved on Friday; On the other hand, subjects primed with the Object-moving spatial schema were more likely (70%) to respond using the corresponding temporal schema, saying that the meeting has been moved on Monday. Therefore, participants of this experiment couldn't ignore irrelevant spatial information in making temporal judgment, suggesting that spatial conceptual structure are involved in our temporal reasoning.

And this effect of spatial information, or spatial experience on temporal thinking has been found not only in the laboratory, but also in more ecological setting like, for example, the queue in a university restaurant at lunch time. Boroditsky & Ramscar (2002) asked to some student that were in line for having a lunch in the restaurant at

Stanford University the "Wednesday meeting question", in the meantime they registered at which point of the line the subject was when he answered the question. The results showed that the more the subjects were close to the food, (i.e. the more they have moved), the more were likely to respond using the ego-moving schema. In other words, the best predictor of which temporal schema the students are going to use is the amount of forward spatial motion that they had just experienced.

Similarly, in another experiment, at the Airport of San Francisco, Boroditsky & Ramscar (2002) asked the "Wednesday meeting question" to people that either were waiting for someone to arrive, or waiting to depart or had just flown in.

They found that people who had just flown in were more likely to take the ego-moving perspective on time (to think of them-selves as moving through time) than people who had not yet flown and were waiting to depart, and both of them were more likely to use the ego-moving schema than people that were waiting for someone. These finding suggests that just thinking about spatial motion (without being explicitly asked to imagine it) is sufficient to change one's temporal thought.

## 5.3 Do we need space to think about time?

Since now, we have provided evidences that space and time are related in our mind, and that we use spatial conceptual structures to think about time, as well as we use spatial language to talk about time. These results, especially the ones from the studies presented in the latter paragraph, allow us to reject one of the most important criticisms moved against cognitive linguists almost from the beginning, namely the fact that evidences of a metaphorical organization of abstract thought are based on the only analysis of linguistic expression, and that nonlinguistic evidences are required before one can accept any aspect of the possibility that people conceptualize of many experiences in terms of metaphor (Murphy, 1996). Nevertheless, in order to accept 'any aspect' (which is not our goal) of the metaphor theory, and especially of the metaphorical representation of time, much more work has to be done. Actually, more work has been done, compared to what we have presented here, and we will review it in the course of this thesis. Moreover, we will try to give our personal contribution in getting closer to the solutions of some of the major problems that remains open about the relationship between time and space in our mind. Many 'aspects' of the metaphor theory have to be tested, and many questions are still waiting for an answer.

In the second part of this thesis, the (relatively) big question that moved our researches was: *Which kind of relation is the relation between space and time in our mind?* This is an important question because not only metaphor theory presupposes that time and space are strictly coupled in our mind (even Locke thought they were!), the novel aspect stands in claiming that this relationship is metaphorical. Two important implications of this claim are:

1) the relationship between time and space in our mind is asymmetrical. As we usually speak about time in terms of space, more than vice versa, our representation of time should be based on our representation of space, more than vice versa. In other words, in a metaphorical relationship, the process of mapping is largely asymmetrical, meaning that most of the times it goes from the source domain (concrete and more sensorial based) to the target domain (abstract and less sensorial based). Therefore, according to metaphor theory, in our mind, time should depend on space more than vice versa.
2) the relationship between space and time is learned and not innate. We learn to think about time in terms of space through the everyday experience and interaction with the environment.

Moreover, we should add that these claims could be adequate at one explanatory level but not at another. For example, we could suppose that the relationship between the conceptual domains of space and time is asymmetrical when we are engaged in linguistic reasoning (or when we are *thinking for speaking,* Slobin, 1996), but not when we are engaged in low level cognitive processes like estimating the duration of a song or the size of a bench (Casasanto & Boroditsky, 2008; Bottini & Casasanto, 2010); maybe, space and time can be symmetrically related in the childhood, or even infancy (during the period of *conflation*, or because of their innate structure) and become asymmetric later in the development (Casasanto et al. 2010; Srinivasan & Carey, 2010; Lourenco & Longo, 2010); and other possibilities can be considered. The data we have presented until now cannot fulfill these doubt. Therefore, in Part II, we'll present and analyze a recent proposal by the neuroscientist Vincent Walsh (Walsh, 2003). Walsh suggested that space, time and number are symmetrically interrelated in our mind and brains, because they are part of a common magnitude system, biologically evolved. After an exhaustive review of the evidences and counterevidences about this *Theory of Magnitude* (ATOM), we will review evidences for the 'metaphor theory' and we'll test the theory of space-time asymmetry in two novel experiments. Not only ATOM could be se against to metaphor theory because it claims that the relation between space and time in our mind is symmetric, but also because it claims that space and time, in our brain (and, Walsh might say, therefore in our mind) are coupled from the birth, because the space-time association is a product of biological evolution. As we will see a similar conclusion about a 'innate functional overlap' between length and duration, has been recently suggested by Mahesh Srinivasan and Susan Carey (Srinivasan & Carey, 2010), in syntony of the analysis by Steven Pinker (1997; 2007) on metaphorical thought. We will try to approach this version of the classic problem of *nature* vs *nurture* at the end of the second part. Indeed, questions about the role of (sensory-motor, cultural and linguistic) experience on the metaphorical construction of the concept of time will accompany the reader for the all thesis.

# PART 2
# The space-time asymmetry

## Introduction: Independence, symmetry, asymmetry.

Which kind of relationship is the relationship between space and time in our mind? In principle, three kinds of relationships are possible.[68]

1) Temporal and spatial reasoning (perception, conceptualization) could take place in our mind *independently* to each other. We can call this hypothesis the "Kantian hypothesis", according to which temporal and spatial thinking are based on two independent and autonomous conceptual structures (and probably neural structures as well), which can be similar to some extent (maybe because of a common evolutionary history, [Pinker, 1997]), but usually work separately. According to such a hypothesis, temporal and spatial thinking should never or rarely overlap, and the activity of one system should not significantly influence the activity of the other system, and vice-versa.

2) Temporal and spatial reasoning (perception, conceptualization), could be linked in our mind by a symmetric relationship. We can call this hypothesis the "Lockian hypothesis", according to which temporal and spatial thinking share some of their conceptual structures and/or the activity on the system regularly influence the activity on the other system, in a mutual symmetric interaction.

3) Temporal and spatial reasoning (perception, conceptualization), could be linked in our mind by an asymmetric relationship. We can call this hypothesis the "Bergsonian hypothesis", according to which temporal and spatial thinking share some of their conceptual structures and/or the activity of one system regularly influences the activity of the other system. Nevertheless, this relationship is asymmetric because one system depends on the other (functionally and/or structurally) more than the other way around. According to Bergson, for example, our representation of time is largely based on our representation of space, but not vice versa. Obviously, the relationship could go in the opposite way, with spatial thinking that is dependent on temporal structure

[68] This tripartition does not have to be taken in absolute terms, but just as a simplified range of possibilities adequate to introduce the problem. The relation between space and time could be different at different level (perceptual, conceptual, conscious reflection), at different stages of development, under different cultural influence, and so on. Many of this declination of the problem will be deepen in this thesis.

more than vice versa. Therefore, according to this hypothesis, the activity of one system should influence the activity on the other system more than vice versa.

The theoretical approach that we have proposed at the end of the previous part, and that we'll call from now 'Metaphor Theory' (Lakoff & Johnson, 1999; Boroditsky, 2000; Casasanto & Boroditsky, 2008; Casasanto, 2008b), can be ascribed to the third view. According to Metaphor Theory, spatial thought is primary in respect to temporal thought, and at least part of our concept of time is based on conceptual structures, cognitive processes and probably neural networks, which originally underlie our understanding of spatial relations. A superficial analysis on the temporal and spatial expression in many languages is enough to acknowledge that spatial metaphors are used to talk about time much more than the other way around (Clark, 1973; Alverson, 1994; Traugott, 1978; Lakoff & Johnson, 1999), the etymology of many temporal terms reveal the priority of space through linguistic changes in history (see, 5.2.2 ), and studies in language acquisition suggest that something similar happens in the ontogenesis (see Clark, 1972 and 5.2.1 ). Moreover, also the studies carried-on by Piaget on the construction of the concept of time in the child (Piaget, 1927) has provided clear evidences of the priority of the understanding of space and motion in respect of time.

Crucially, psychological studies with grown up subjects which supposedly mastered an accomplished concept of time, have shown how irrelevant spatial information can interfere and influence our temporal judgments, suggesting a functional overlapping between temporal and spatial reasoning (e.g. Miles et al. 2010; Borodisky, 2000; Srinivasan & Carey, 2010). As remarked elsewhere (Bottini & Casasanto, 2010; Casasanto et al. 2010; Srinivasan & Carey, 2010), these results, although important, are not enough to fully support metaphor theory and accept the 'Bergsonian' version of the space-time relationship described above. Indeed, these data allow the experimenter to rule out the hypothesis that space and time are completely independent in the human mind (hypothesis, however, extensively falsified from a long time Benussi 1913; Price-Willams, 1934; Jones & Huang, 1982), but leave the door open to the "Lockian" and "Bergsonian" hypothesis: the observed results for which spatial information can influence temporal judgments can be explained also supposing that space and time are symmetrically linked in our mind.

In this part of the thesis we will review studies and provide new evidences that support metaphor theory and challenge other competing “Lockian” theoretical frameworks. One of these theoretical proposals, which become significantly relevant in the field of cognitive neuroscience, has been chosen here as competitor of the Metaphor theory. According to this proposal, space and time are represented in the brain and mind by a common analog magnitude system, which also generates representations of number and quantity. This view, summarized in Walsh’s ATOM (A Theory of Magnitude; 2003), is consistent with neurological data showing shared brain areas for processing space, time, and quantity, and with many behavioral studies in animals and humans. Implicit in ATOM is an assumption that these ‘ATOMic’ dimensions are symmetrically interrelated: not hierarchically related in the brain/mind. Accordingly, Walsh (2003) frames predictions in symmetrical terms, positing “overlapping brain regions” and “cross-domain, within- magnitude priming” between dimensions, without specifying any *directionality* to the priming (or interference) effects. Indeed, if space and time are both manifestations of the same general-purpose analog magnitude system, there may be no *a priori* reason to posit that one dimension should depend asymmetrically on another. A deep analysis of this theory will open this part of the thesis.

As we will see, even if compelling evidences seem to have driven some aspects of the diatribe between symmetry and asymmetry to a sound conclusion, other aspects are still need a clarification. Moreover, as anticipated before, the space-time asymmetry is also an ideal testbed for another important aspect of the Metaphor Theory, namely the experiential nature of the spatial basis of the concept of time, opposed to an innatist view.

# 6. A Theory Of Magnitude

## 6.1 A common magnitude metric for space, time and numerosity.

One of the commonalities between the categories of space, time and quantity, it's that they can be represented as magnitudes, and often they are. Of course, we are able to represent temporal magnitude distinct to spatial and numerical magnitudes, and this ability is probably crucial in order to reinforce the perceived independence of these categories both in what we called the outside world and in our thought. For example we are perfectly able to make independent judgment on the duration of a movie, the size of the movie theater, and the number of people seat in the gallery. Or, when we prepare a 20 minute talk for a scientific conference, we usually don't average the duration of the talk with the dimension of the conference room and, for similar reasons, we don't expect the chairman to communicate us the remaining time according to how many people left the room during the presentation (unless he's willing to leave the room too, because of the quality of the talk!). Time, space and numerosity are different features of the world (at least the world we usually perceive), and we can easily think about its separately, avoiding such a funny reasoning. As we have already seen, one of the goals of this thesis is try to scratch this well-knit belief. And, in a different way, that's also the goal of Vincent Walsh's *Theory Of Magnitude*.

Some years ago (Walsh, 2003), Walsh tried to put together three different scientific literatures, on time, space and numerosity perception, in what he called "A Theory of Magnitude" (ATOM). According to ATOM, the representations of time, space and numerosity share in the human mind, and brain, a common magnitude system useful to compute the information coming from those three different domains in terms of 'more than/less than'. Longer to create the funny confusions considered above, a common system for magnitude processing is useful to integrate magnitude information coming from the environment (like spatial and temporal cues) in order to coordinate and perform action and behavior. Moreover space, time and quantities are closely related in our everyday experience: if we walk for a long distance we usually also walk for a long time, large quantities often need more space than less quantities of the same item, and the more object we have, the more time we have to spend in order to interact with each of them. Following Gallister and Gelman:

> "countable and uncountable quantity (numerosity and amount, duration, etc.) should be represented with the same kind of symbols (mental magnitudes), because there are many cases in which the two kinds of quantity must be combined...to determine behaviourally important decision variables" (Gallister & Gelman, 2000, p.62)

The emphasis on action coordination is central in ATOM, because the need of integrate spatio-temporal information for motor action performing could be the bootstrapping for the evolution of a common metric that, successively, has been extended to others prothetic[69] domains:

> "Temporal and spatial information are of course necessary for action: for reaching, throwing, pointing and grasping, and the objects at which we direct these actions are frequently moving. Space and time can easily be segregated in psychological experiments by immobilizing subjects' heads, eye movements, restricting their actions and presenting stimuli briefly, but in everyday activity, space and time are rarely segregated—there is no such thing as getting to the right place at the wrong time: if you throw, point, reach or attempt to grasp a moving target, you need to estimate space and time accurately." (Bueti&Walsh, 2009, p. 1832)

According to Bueti&Walsh (2009) it is economical, in term of biological evolution, to develop the capacity of counting and discern different numerosity using a system that "*is already equipped with an analogue system for action that computes 'more than–less than', 'faster–slower', 'nearer–farther', 'bigger–smaller', and it is on these abilities that discrete numerical abilities hitched an evolutionary ride.*" (Bueti & Walsh, 2009, p. 1832).

A good test of common resources being shared across magnitudes is to look for examples of behavioural interactions between them, and if this evolutionary story is correct, those interactions should exist across species. As reported by Walsh, similar behavioral function in estimated time and numerical quantity has been reported in non-

[69] A term introduced by Stevens (1975), meaning all the dimensions that can be experienced in as "more" and "less". Apart from space, time and numbers, other prothetic dimensions are loudness, pitch, quality, brightness, speed, etc.

human species. For example, Church and Meck (1984) showed that rats are able to generalize learned behavioral patterns in magnitude discrimination across the numerical and temporal domain. Trained to discriminate small quantities, between 2 and 8 tones, rats learn to recognize a 4-tones stimuli as half-way between the two anchor values. Surprisingly the rats could apply the same learned strategy to recognize a middle duration tone between a 2- and a 8-seconds tone, suggesting a shared mechanism for magnitude comparisons. Coming up along the evolutional scale, non-human primate studies show that two spatial processing areas (the inferior parietal lobe (IPL) and the dorsolateral prefrontal cortex (DLPFC)) contain neurons selective for numerical quantity (Sawamura et al. 2002; Nieder et al. 2002; Walsh, 2003b) and temporal duration (Onoe et al., 2001; Leon et al. 2003). [see figure 8]

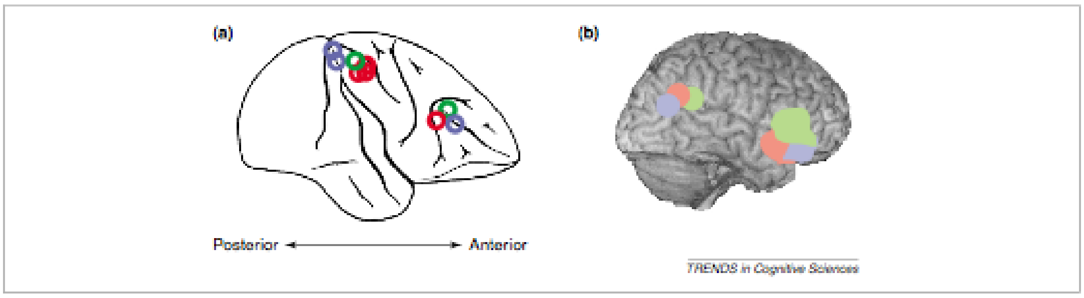


Figure 8: Comparative anatomy of the anterior and posterior magnitude system in monkey (a) and human (b) brain. In (a) the circles correspond to observed neural activation for spatial (red), numerical (green) and temporal (blue) stimulations.

According to Walsh, a homologue of this magnitude system exist in the human brain as well. The picture in *Figure 1* is accurate for the posterior magnitude system, that according to Walsh is located in the right parietal cortex, more precisely in the right Intraparietal Sulcus (IPS). But, contrary to the monkey brain, the anterior magnitude system is located, in the human brain in the left pre-frontal cortex (PFC). In this magnitude system (that should include also other cerebral areas as those involved in spatial (V3) and motor (V5/MT) processing (Walsh, 2003)) the Parietal Cortex, and especially the right-IPS is considered the 'primary magnitude cortex' (Bueti & Walsh, 2009) both for the constant activation reported in many studies on temporal, spatial and numerical processing (see later, in this chapter) and for the close relation to motor-action processing and performing:

"…why the parietal cortex, of paramount importance here, should contain sub-regions that are important for reaching, grasping, space, quantity and time [?]. Cajal noted that 'All natural arrangements, however capricious they may seem, have a function' (Cajal, 1898/1999, p.119), and here I argue that the arrangement of the inferior parietal cortex reflects the common need for space, time and quantity information to be used in the sensorimotor transformations that are the main goal of these areas of cortex." (Walsh, 2003, p. 483)

The strategic role of the parietal cortex in the sensorimotor interface make this region of the brain a sensible candidate to host a (still) hypothetical common magnitude system, originally dedicated to the integration of spatial and temporal information for acting in a certain environment, and lately recycled (or, to use a more technical term 'exactated') for magnitude processing of numerosity and other prothetic domains (luminosity, loudness, etc.) even when motor action is not involved (Bueti & Walsh, 2009).

In this process of exactation, for which a simple sensorimotor mechanism dedicated to the integration of spatio-temporal information become the basic mechanism for the representation of magnitudes in different prothetic domains and different modalities, is the beauty and the elegance of ATOM.

To sum-up:

1- space, time and numerosity (and other prothetic dimensions) are linked by a common metric for action; then, time, space and numerosity estimation operate on similar and partly shared accumulation principles.

2- the inferior parietal cortex, and especially the right-IPS is the locus of this common magnitude system

3- the apparent specializations for time, space and quantity develop from a single magnitude system operating from birth, philogenetically evolved, homologue of other magnitude systems operating other species' minds.

If this is the case, space, time and quantity are strictly linked in our mind more that what we usually think. Like in animal behavior, a good way to test for this hypothesis for human minds it's to look for examples of behavioral interaction between magnitude processing. Without reaching the counter-productive confusions described at the beginning of this chapter, it should be the case that interference from one of the three domains (i.e. numerical information) influence magnitude processing in the other domains (i.e. temporal or spatial estimation), moreover "experiments in which responses are made to two or more magnitudes on successive trials should show cross-domain, within-magnitude priming" (Walsh, 2003a, p.484). According to Bueti & Walsh:

> "One prediction from ATOM is that there should be some monotonic mapping of quantities: bigger, faster, brighter, further in one domain should correlate with bigger, faster, brighter, further in another." (Bueti & Walsh, 2009, p. 1832)

The cross-domain interference should work in the form of a "more A – more B" mapping between magnitude, for which, when two or more magnitudes are processing together, to an increase (decrease) of magnitude in one domain should correspond an increase (decrease) of magnitude in the others domains, and vice-versa. In the next part of this paragraph we will consider different studies that provide evidences for these cross-domain interactions (Space & Quantity; Quantity & Time; Space & Time). After that, we will consider neuropsychological, brain imaging and transcranial magnetic stimulation studies, which provide evidence for the cerebral location of a common magnitude metric in the right parietal area and, especially, in the right Intraparietal Sulcus.[70]

## 6.2 Behavioral evidences for a common magnitude metric

### 6.2.1 Space and quantity

The relationships between number and spatial representation has been studied from a long time. Probably, the most famous paradigm used to study the cognitive link between space and numbers is the so-called SNARC-effect (Dehaene et al, 1993; but see Wood et al. 2008, for a recent review). SNARC is an acronym that stand for Spatial

[70] This modality of presentation could seem too schematic, but it has been chosen in order to replicate the structure of the first ATOM paper (Walsh, 2003) in order to provide an up-dated version of the pro-ATOM evidences accumulated in the last 7 years.

Numeric Association of Response Codes, and it's a very simple effect: people usually associate relatively small numbers with the left side of the visual field, and relatively big numbers with the right side. In different kinds of task (i.e. parity judgment, magnitude comparison) people are faster when they have to react to a small number pressing a key on the left and to a large number pressing a key on the right, than the converse. Those results suggest that numbers are mentally represented as a number line where the smaller magnitudes are on the left and the bigger on the right, like the centimeters on a ruler. This orientation is independent of handedness or hemispheric dominance (the effect is not reversed performing the task with crossed harms, Deahene et al. 1993; but see Wood et al. 2006 for a failure of replication), is linked to direction of writing (is reversed for people that write from right to left, Deahene et al. 1993; Shaki & Fischer, 2008) and it's relatively flexible and can be faded changing contingent contextual information (the SNARC can easily be softened, nullified or even reversed by instruction, Bächtold, Baumüller, & Brugger, 1998; by an interleaved task with conflicting spatial mapping, Shaki & Fischer, 2008; or by spatial position of irrelevant numerical information, Fisher et al, 2010).

A linear representation of number is thought to be responsible also for another famous spatial effect called *distance effect*: the further apart two numbers are, the easier one finds it to compare them. The mechanism proposed to explain this effect is that people make magnitude comparisons between the location of the numbers along the 'mental number line' (Dehaene et al. 1998).[71]

Another interesting interaction between space and number can be seen in the size-number interference in Stroop-like paradigms (Besner & Coltheart 1979; Pinel et al, 2004; Kauffman et al., 2005; Hurewitz et al 2006). In this paradigm two digits are presented simultaneously, and they vary both in numerical value and physical size. Sometimes the relation between value and size is congruent, so that the higher number is physically larger than the lower number (i.e. 8 - 2), sometimes the relationship is incongruent with the higher number physically smaller than the lower one (i.e. 8 - 2). In this kind of experiments subjects are usually asked to compare either the physical size

[71] The effect occurs even when the distance between numbers is constant, but the numbers vary in magnitude (so that it is more difficult to decide which of the number 'eight' and 'nine' is the larger, than to decide between 'two' and 'three'), and also when dots, words or mixtures of words and digits are presented rather than numbers alone. The distance effect is also seen in non- human species.

or the numerical value of the numbers. In the value judgment people cannot ignore the irrelevant size information and responds faster to the congruent than to the incongruent conditions. Likewise, in the size judgment conditions participant cannot ignore the irrelevant numerical information.

A similar Stroop-paradigm has been used by Dormal & Pesenti (2007) to investigate the relation between (spatial) length and non-symbolic numerosity. Participants were asked to compare either the numerosity or the total length of arrays of dots, the two dimensions were manipulated in order to create congruent, incongruent and neutral[72] trials. Results showed that the spatial cues strongly interfered with the processing of numerosity, whereas the numerical cues only moderately interfered with the processing of length.[73]

Those findings, so far, don't contradict (if they don't even support) the idea of a common magnitude system proposed by Walsh.

### 6.2.2 Time and quantity

Not only number and space, but also the representation of number and time seem to be somehow related in the human mind. Kiesel & Vierk (2009) for example, found a SNARC-like association between numbers and duration. People were faster in judging parity of small number with a short-time button press, and big number with a long-time button press. Moreover the overall button-press duration was shorter for small number and longer for big numbers. Those results are consistent with a previous study (Xuan, Zhang, He, and Chen, 2007), in which participants were asked to judge which of two numerical stimuli displayed in succession was presented for a longer duration. The paradigm was a Stroop-like one when, sometimes, higher digit was presented for longer time and lower digits for shorter time (congruent condition), and sometimes the duration-value association was inverted (incongruent condition). Participant judging the duration of the digits couldn't ignore the irrelevant numerical value, making more errors in the incongruent than in the congruent condition. A similar effect for which the duration of high digits (i.e. 9) was over-estimated and the duration of low digits (i.e. 1)

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[72] In the neutral trials the irrelevant dimension remain un-changed between the two stimuli to be compared.

[73] About this and others interference asymmetries between dimensions we'll talk about later on this work.

was under-estimated compared to a reference fixed stimulus (i.e. 5), has been observed by Olivieri ta al. (2008). Likewise, Mo (1971, 1975) found that the number of dots on a given surface would lengthen the perceived duration.

Using another Stroop-like paradigm, Dormal et al. (2006) manipulated the duration and the numerosity of a series of flashing dots in order to create congruent, incongruent and neutral trials. Participants had to compare either the number of dots in a two different series, or the total duration of the two series. The irrelevant (and non symbolic) numerical cues implicit on the stimuli modulated the duration estimation (higher reaction time/error rate in the incongruent condition compared to the congruent and neutral one) showing that participant couldn't ignore irrelevant information of numerosity when making a duration judgment.[74] Similar results were observed in adults and in 5- to 8-year-old children during a task which involved bisecting a series of dot displays flashed for 2–8 sec (Droit-Volet et al., 2003).

### 6.2.3 Time and space

Many studies show cross-dimensional interference between space and time. De Long (1981) showed that people interacting with different scaled environment undergo systematic shifts in time experience. In this experiment participants were asked to carry on task in different environments that was scaled as 1/6, 1/12 or 1/24 of the actual size, and stop when half hour were passed. Surprisingly, the estimation of the 30 minutes temporal interval was compressed, relative to the clock time, in the same proportion as scaled model environments were compressed relative to the 'actual' size.

In developmental Psychology, the study of the concept of time arise from the pionieristic studies by Jean Piaget (1927/1969), which we have already considered, although briefly, in a previous part of this work (see 5.2.3). Some of the early studies by Piaget clearly show space-time cross-dimensional interference. In one of this experiment the child was watching two small figures moving across a table. The figures moved at different velocities, started from the same spot at the same time, and stopped in a different spot at a different time. The experimenter than asked some questions like: "Do the two snails moved for the same length of time?" and, if not, "which one of them

[74] On the other hand, irrelevant duration didn't affect numerosity judgment, showing the unidirectionality of the cross-domain interference.

moved longer?"; "Do the figure stopped at the same time?" and, if not, "Which one stopped first?". Children between 4 and 7 years answered the question on the basis of spatial length of displacement of the figure, instead of the duration of the displacement. For example, if the figure one moved for 20 cm in 10 seconds, and the figure two moved for 10 cm in 20 seconds, the children claimed that figure one moved for a longer time, because it went further! Temporal judgment were taken on the basis of spatial information.

In a Piaget-like experiment, Stavy and Tirosh (2000; quoted in Bueti&Walsh, 2009) asked to some children to estimate which of two trains traveling in parallel path was the faster. Children were often influenced on they speed judgment by the size of the trains reporting that the larger train was also the faster one, even if it wasn't true.

Among the others, a great contribution to the development of time-understanding in children and it's interaction with others dimensions has been provided by the work of Iris Levin (Levin, 1977; 1979; Levin&Gilat, 1983; Levin et al. 1978; 1984a; 1984b; 1990). If asked to compare the burning time of two lights (Levin et al. 1978), children were influenced both by the brightness and the size of the light (i.e. brighter/ bigger lights were judged to last a longer time than dimer/smaller lights). Similar cross-domain interferences have been found in the interaction between duration, rotation speed (without displacement), and linear displacement (Levin, 1977; 1979).

But not only children make often confusion between space and time. Many studies shows how this cross-domain interference is still present in the adulthood as well.

Wuan et al. (2007) showed how task-irrelevant, non-temporal magnitude information can influence time estimation in healthy people. This experiment used a Stroop-like paradigm in which participant had to estimate the duration of different stimuli: groups of dots with different numerosity, open squares with different size, solid squares with a different degree of luminance and digits with a different numeric value. Results showed that stimuli with larger magnitudes in these non-temporal domains were judged to be temporally longer according to the prediction of the "more A – more B" mapping. Virginie van Wassenhove and colleagues (van Wassenhove et al., 2008) demonstrated that this cross-domain interaction between time and space is possible also between modalities of perception. In one of the experiment of this study, participants were presented with incongruent audio-visual stimuli (i.e. a looming circle with a pure tone, or a steady circle with a looming tone) and asked to pay attention either to the visual or the auditory characteristic of the stimuli. The perceived duration of the tone (auditory) were modulated by the spatial feature of the stimuli (visual), so that, for example, a progressive augment of the size of the circle make the co-occurrent tone seem longer showing an interference effect across perceptual modality.[75]

From the beginning of the last century, psychophysical experimentations on spatial and temporal judgments, have produced what have been called the Tau and Kappa effects, two classic effects that have been replicated several time (i.e. Benussi 1913; Price-Willams, 1934; Jones & Huang, 1982; Sarrazin et al, 2004). In the classical paradigm, three light bulbs are arranged in a row and flashed one after the others, so that two spatio-temporal intervals were created. Subjects were asked to compare either the spatial or the temporal extent of the two intervals. Temporal judgments were influenced by the relative spatial distance of the intervals (i.e. increased temporal judgment for increased spatial separation) even if the duration of each interval were maintained constant (Kappa effect); spatial judgments were influenced by the relative temporal distance of the intervals (i.e. increased spatial judgment for increased temporal separation) even if the space of each interval were maintained constant (Tau effect).

Another space-time interaction predicted by Walsh (2003) was the presence of SNARC-like effect for temporal (and other magnitudes) representations. Ishiara et al. (2008) tested what has been called the STEARC-effect (Spatial TEmporal Association Response Code) by presenting to the participants 8 sounds, one after the other, with the same temporal interval between each sound except for the last one that was either delayed or anticipated.  Participants had to decide if the last sound was played sooner or later by pressing two buttons. One on the left and one on the right (or, if you like, one with the right and the other with the left hand). The key position was switched to create a congruent and un-congruent condition according to the direction of a mental time line that should go (as the mental number-line) from left to right (with the ‘past/early’ on the left, and the ‘future/late’ on the right). Participants responded faster in the congruent condition (left button for early on-set timing/ right button for late on-set timing) than in

[75] On the other hand, the perceived duration of visual events was seldom distorted by the presence of auditory information.

the incongruent one (right button for early on-set timing/ left button for late on-set timing). Nevertheless, such a time–response congruity effect was not observed with the vertical alignment of responses.

Similarly, Santiago et al. (2007) had shown that healthy subject are faster in categorising words as referring to the past with the left hand (or when the words appear on the left space), and as referring to the future with the right hand (or when the words appear in the right space), compared to the opposite spatial response code. Vicario et al, (2007) showed that optokinetick stimulation (point or lines on the screen that move leftward or rightward) also affect time estimation. Rightward OKS induce a significant time over-estimation compared to baseline and leftward OKS, but this effect was shown for sub-second but not for supra-second interval. In a subsequent study (Vicario et al., 2008) for digits displayed either on the left or on the right of a computer screen, the duration of number presented on the left side was under-estimated and the duration presented on the right side was over-estimated, regardless of digit magnitude. Weger & Pratt (2008) have shown that subject were faster categorizing old Hollywood celebrities pressing a key on the right and young celebrities pressing a key on the left, and slower with the opposite spatial mapping. Vallesi et al. (2008) had shown that people are faster categorizing long duration pressing a key on the right and shorter duration pressing a key on the left and slower with the reversed spatial configuration, regardless which hand are they using (then excluding manual or hemispheric asymmetry explanation ). Conson et al. (2008) showed that people asked to judge whether the first or the second tone in a pair was shorter (or longer) responding by pressing a left or a right key, are more accurate in conditions where the first tone was shorter or the second tone was longer, with no effects of the position of the response keys. But, in a subsequent experiment, a modification of the response-paradigm demonstrate the presence of a SNARC-like effect, evidencing an interaction between order and response key, and a second-order interaction among duration, order and space.

These findings,[76] apart from being compatible with ATOM's predictions of cross dimensional interference between space and time, are in line with the hypothesis

[76] In this paragraph we limited the review to studies that show a space-time interference. Nevertheless it is possible to show other kind of evidences supporting the relations between space and time. For example Paul Fraisse (1963) was one of the first that described similarities between spatial and temporal perception. For example, spatial gestalt laws like 'assimilation'

that time can be represented along a left-to-right oriented mental time-line, a spatial representation that will be deeply investigated in the third session of this thesis.

## 6.3 Neuropsychological, brain imaging and transcranial magnetic stimulation evidences for a presence of a common magnitude system.

The neural location suggested by Walsh for the general magnitude system is the parietal lobe, and, more accurately, the right Intraparietal Sulcus. This proposal is supported by many findings in different fields as neuropsychological, brain imaging, and transcranial magnetic stimulation studies.

### 6.3.1 Brain damage

If space, time and numbers share the same neurological magnitude system, a damage in dedicated areas should impair performances in all those three domains. Some neuropsychological studies provide data to support this hypothesis (see Koch et al. 2009 for a review).

Bueti & Walsh (2009) pointed out that brain damage that cause temporal deficits also frequently cause spatial, numerical, and velocity perception deficits (e.g. Cipollotti et al. 1991, Battelli et al. 2003; Becchio & Bertone, 2006; Danckert et al. 2007; Cavezian et al. 2007; Zamarian et al. 2007 [quoted in Bueti&Walsh, 2009] ). For example, Basso et al. (1996) tested a patient with left-spatial neglect on a short duration estimation task (300 vs. 700 ms). The subject consistently overestimated durations of stimuli presented in the neglected space and underestimated duration of stimuli presented on the other hemi-visual field. Likewise, Danckert et al. (2007), tested right brain damaged persons in a temporal task that consisted in verbal reproduction of supra-second intervals. Patients with a spatial neglect had the worst performances in this time-reproduction task, showing a significant under-estimation of the temporal intervals compared both to control and other RDB patient.

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(i.e. the tendency to minimize small differences) and 'contrast' (i.e. the tendency to exaggerate appreciable differences), apply to temporal perception as well. Moreover, the phenomenon according to which, for equal duration, a temporal interval with more divisions seems longer than one with less divisions (See chapter 3) can be intended as the temporal version of the Oppel-Kundt illusion (a linear space, subdivided into a number of segments, is usually reported to appear longer than an undivided one of equal length).

Zorzi et al. (2002) showed that patients with hemispatial neglect misplace the midpoint of a numerical interval when asked to bisect it (for example, stating that 'seven' is halfway between 'one' and 'nine') providing evidence that a spatial impairment correspond to a numerical impairment disrupting the mental number line, an effect that has been replicated (Priftis et al. 2006; Vuilleumier et al., 2004; but see Doricchi, Guariglia, Gasparini, & Tomaiuolo, 2005 for different results). Nevertheless, in some cases, a damage of the left Inferior Parietal Cortex, disrupt numerical performance but leave intact spatial and temporal performance (Walsh 2003; Cipolotti, Butterworth, & Denes, 1991; Lemer, Dehaene, Spelke, & Cohen, 2003) suggesting a different lateralization for numerical and spatial-temporal representation. Walsh suggests that these data can be compatible with ATOM giving the following explanation

> "Cohen and Dehaene have suggested that the inferior parietal cortex in both hemispheres is essential for analogical quantity representation (1996). [...] it is clear that left IPC damage can selectively disrupt number processes whereas right IPC is more critical for spatial and temporal processing. According to Dehaene (1992), only the left hemisphere can use the verbal coding required in calculation. Therefore, a patient with left parietal damage might be able to make analogical number comparison, but this knowledge will be disconnected from left hemisphere language systems." (Walsh, 2003, p. 485)

According to Walsh the hemispheric asymmetry between number and space and time is a consequence of the verbal encoding of the output of numerical processing. This lateralization take place in the ontogenesis , but representation of quantity, space and time start out from the same magnitude system located in the rIPC. This view is supported by studies that show an overlapping populations of magnitude neurons in homologous regions of monkey cortex (Thompson et al, 1970; Sawamura, H. et al 2002; Nieder et al, 2002; Onoe et al. 2001; Leon & Shadlen, 2003; see Walsh 2003 for a short review), providing evidences for a evolutionary continuity.

### 6.3.2 Imaging

Activation of the parietal regions for time, numbers and space independently has been consistently reported (see Cappelletti et al. 2009, for a review), but in this section we'll review some neuroimaging studies that contemporary focus on at least two of those three dimensions together.

Kaufmann et al. (2008) compared adults and children (mean age 8.6) engaging non-symbolic numerical and spatial discrimination, (using a color discrimination task as a control). Considering spatial and numerical tasks together, children showed relatively more activation than adults in the supramarginal gyrus, the lateral anterior intraparietal sulcus (IPS) and the precentral gyrus, but surprisingly, there were not supratreshold parietal activation for spatial tasks only. Joint cerebral activation patterns in response to non-symbolic numerical and spatial processing (conjunction analysis) in parietal regions were found in adults only, [77] being located at the right superior parietal lobe (including the IPS). Those results suggest the possibility of some age related variation in the magnitude processing of which we'll talk about later in this work. More clearly, Choen-Kadosh et al.(2008b), found a modulation of the right IPS correspondent to a number/luminace Stroop-like interference task.

Walsh noted that many studies suggest that the IPS is important for time perception (Rao et al. 2001; Mohl and Pfurtscheller, 1991; Harrington, and Haaland, 1991), even if the temporal deficit is usually less salient and may be hard to detect than the spatial one. If some studies didn't obtain a time-related activation in the parietal cortex (Maquet et al. 1996; Pouthas et al. 2000; Fias W. et al, 2003; Tracy et al., 2000) that's because, according to Walsh, others magnitude-related tasks have been used as a control. An exemplar case is Maquet et al. (1996), where a rIPS activation for duration judgment was obtained when the control task consisted on pressing a key in response to a LED illumination (non-magnitude task), but disappear when the response task consisted in judging the intensity of the LED (magnitude task) (Walsh, 2003).

According to Olivieri et al. (2008), evidence for ATOM can be find in studies that show the link between space, time and quantity with motor planning

> "Functional imaging studies show that arithmetic […], number comparison […], or the quantitative processing of non-numerical stimuli (Pinel et al., 2004), activate parietal and premotor areas close to those involved in object manipulation or grasping […]. Thus the same cortical network involved in the coding of numerical values, seems to operate in parallel with

[77] The authors explain this null result referring to interindividual differences in cerebral responsiveness.

the motor programs recruited for the transformation of object size into an appropriate hand posture" (Olivieri et al. 2008, p. 308)

Although those studies involved a bigger portion of the bilateral parietal areas than the rIPS, are important to quote considering that according to Walsh (Walsh, 2003; Bueti and Walsh 2009), we learn about space and time (and about the association between space, time and others magnitude) through actions, making action-relevant magnitude comparison or estimation. This action-relevant magnitude system is successively co-opted for magnitude processing non relevant for action, or for discrete and symbolic representation of magnitude. A proposal, this one, that we'll re-consider several time before the end of this thesis.

Many brain-imaging studies stress the central role of the IPS for number processing (see Dehaene et al. 2003 for a review). A specific contribution of the right IPS to numerosity and length processing has been reported by Dormal & Pesenti (2009). Similarly, bilateral IPS activation has been found for both numerosity and size processing across different studies (Pinel et al. 2004; Coen-Kadosh et al. 2005; Tang et al. 2006).

### 6.3.3 TMS

Not only the imaging techniques, but also studies using Transcranial Magnetic Stimulation can be really useful to test the Theory of Magnitude. In fact, magnetic interference in parietal region, especially in the rIPC and the rIPS, should yield deficits on tasks related to time, space, number and other magnitudes. As Walsh pointed out:

> "several studies using transcranial magnetic stimulation (TMS) have shown that parietal cortex stimulation in human subjects can cause deficits in spatial tasks [Bjoertomt, 2002; Rushworth, 2001.] and also in number comparison [Gobel et al. 2001] and time discrimination [Walsh&Pasual-Leone, 2003]." (Walsh, 2003, p. 485)

In the last years, new TMS studies have provided new evidences supporting ATOM.

Alexander, Cowey, & Walsh (2005) have shown how repeated TMS over the right posterior parietal cortex impaired performances in a duration comparison task.

Nevertheless, no effect has been found for another magnitude task like pitch comparison (Alexander, Cowey & Walsh, 2005). Gobel et al. (2006a) reported that rTMS produced representational neglect-like symptoms in number bisection when applied over right posterior parietal cortex (right PPC). Reaction time latency in a numerical addition task has been found after rTMS over the left inferior parietal lobe but not over the right IPL (Gobel et al. 2006b).Knops et al. (2006), stimulated the left IPS[78] of male and female participants with rTMS. They found interesting gender differencies on the effect of rTMS on the *distance effect* and the *compatibility effect*[79] related with numerical magnitude activation.[80]

To conclude, Bueti, Bahrami and Walsh. (2008), conducted an experiment in which

participants received repetitive transcranial magnetic stimulation (rTMS) over the right or left parietal cortex, left MT/V5, or the vertex while they performed one of five different tasks: 4 tasks of temporal discrimination (with visual or auditory stimuli), or a shape identification task as a control. Results show that visual area MT/V5 has a role in temporal as well as in spatial visual tasks, and that this role is specific to the visual modality. Furthermore, we show that the right rather than the left posterior parietal cortex is important for time discrimination of both visual and auditory durations. These results were significant just using the Weber ratio as dependent variable, but not using the PSE (Point of Subjective Equality).[81]

This is, indeed, a good amount of evidence and converging data that support ATOM. More specifically, we can say that at least three of the prediction made by Walsh (2003) in his former ATOM paper has been confirmed. Namely:

1- the spatial numerical association of response codes (SNARC) can be generalized to other magnitudes like space and time. A general spatial

[78] Bueti & Walsh errounesly reported a rightIPS stimulation (See Bueti&Walsh, 2009).
[79] In magnitude comparison tasks responses are faster when decade and unit comparison would lead to the same decision (e.g. 42 57, 4 < 5 and 2 < 7) than when they would not (e.g. 47 62, 4 < 6 but 7 > 2).
[80] No neglect-like symptom were found, and no line-bisection task was done in this experiment, as errounesly reported by Bueti&Walsh (2009).
[81] rTMS had no significant effect on the PSE at any site for all these experiments.

association that has been called SQUARC effect (Bueti&Walsh, 2009, spatial quantity association of response codes).

2- Experiments in which responses are made to two or more magnitudes on successive trials showed cross-domain, within-magnitude priming or interference.

3- Brain regions not considered essential for magnitude processing, also prove to be important, like the BA V5 for time processing (Bueti et al, 2008a,b)

Moreover, the neuropsychological, imaging and TMS data constitute a good number of evidences for a right-IPS location of common magnitude system for spatial, temporal and numerical (magnitude) representation, a "*single developmental algorithm for more than–less than distinctions of any kind of stuff in the external world*". (Bueti & Walsh, 2009).

Nevertheless, those evidences are not definitive, leaving some zones of shadow, unexplained interactions and many open questions. Recent data seems to challenge the ATOMic view of magnitude representation and some of them are in open contradiction with previous empirical results. Those and others critical observation are the material on which the next paragraph is built-up.

## 6.4 ATOM revisited

We can differentiate our efforts to test/falsify ATOM dividing Walsh's proposal in two main questions:

- Are space, time and quantity (and others magnitude) represented by the same metric system in mind and brain, and located in the rIPC?
- What is the nature of the relationships between those three domains? Are those relationships symmetrical or asymmetrical?

In this paragraph we'll address mostly the first question. The second question, with a focus on the relationships between space and time, will be the principle argument of the next chapter.

According to ATOM, a single representational mechanism underpins magnitudes representation of time, space and quantity. This common representational system has been philogenetically developed to compute magnitude information for action processing and performance, and it is innate in human beings. This common magnitude system is only partly shared among magnitude dimensions since each of them is also implemented by dimension-specific processes (Walsh, 2003). The neural location of this common metric is the right Intraparietal Sulcus. In spite of the wide pro-ATOM literature presented above, the assumption that magnitude representation of duration, space and numerosity share the same cerebral and cognitive processes is still under debate. New empirical evidences and theoretical concerns seem to bring into question the elegant explanation provided by ATOM on the nature of magnitude processing.

Recent brain imaging studies failed to find right-IPS activation for magnitude processing, and challenge the ATOMic point of view at the very basis. Shuman and Kanwisher (2004), for example, run subjects in three different tasks comparing non-symbolic numerosity judgment with color or shape categorization as a control. Overall the tasks, a significant activation of the left-IPS was found, but the activation of the right-IPS didn't reach the significance if not using a less conservative statistical analysis (a lower statistical thresholds). Moreover, the study failed to find higher IPS activation for numerical than for color/shape tasks. A failure that can hardly be imputed to insufficient power, since they found (at least in exp. 1 and 3) a significant effect across conditions, but it was in the 'wrong' direction. This finding, in a first place poses a challenge to the hypothesis that the parietal area (especially bilateral IPS) is engaged in representing numerical magnitude for both symbolic and non-symbolic number in a domain-specific fashion (see Dehaene et al., 2003 for review). Moreover it challenges the ATOM point of view that locates the common magnitude metric (especially for non-symbolic magnitude, see Walsh 2003), in the right-IPS.[82]In the last part of the discussion of their study, the authors directly challenge ATOM reasoning like this:

> "…Walsh has proposed a "theory of magnitude" in which time, space, and quantity are all processed by a single parietal "magnitude" system […]. Our results indicate that non-symbolic numerosity processing does not activate the putative parietal magnitude region any more than the same region is activated by a same-different color discrimination task that does not involve magnitude. It is difficult to imagine a coherent theory of magnitude processing that includes symbolic number and the magnitudes of lines, angles, and luminances but does not include assessment of the number of elements in a set." (Shuman and Kanwisher, 2004, p. 566)

More recently, Kauffman et al. (2005), did an imaging study using a size/number interference Stroop-like paradigm, a study that it's worth to take a closer look on. Participants in this study saw pairs of digits that varied in numerical value and/or size. Highly significant *distance* and *congruity* effect, for both size and numerical judgment, have been found at the behavioral level. Nevertheless, the imaging data revealed that only numerical comparison, but not size comparison, compared to null events, activated the IPS (bilaterally). Moreover, the distance effect (comparing low with high distance trials, and only for the neutral trials, without interference) led to an activation of the bilateral IPS, and just in the numerical judgment. No IPS activation has been found for congruity effect (congruent and incongruent trials compared for the neutral trials). The author interpreted the failure to find task-specific activation of the IPS as an evidence for a general (not number-specific) role for the Intraparietal Sulcus in comparison tasks. An interpretation that fits very well in ATOM. Nevertheless, the non-significant activation of the rIPS during the size comparison task, and during incongruent trials compared to congruent trials, leave us with some doubt.[83] Similarly, Ansari et al. (2006), using a passive viewing paradigm where arrays of squares were displayed to the subjects, reported significant activation of the superior IPS (bilaterally), for numerical distance effects, but not for size distance effect.

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[82] It is important to report that at low statistical thresholds, both experiment 1 and experiment 3 yielded right anterior parietal regions with a stronger response to number than color. However, neither activation replicated across the two experiments.

[83] But, in another study that we'll cosider later, rIPS activation has been found for both numerical and size comparison task (Pinel et al., 2004).

Switching from imaging studies to neuropsychology, Cappelletti et. Al. (2009) presented a case study of a patient with right brain damage (RBD) for whom the temporal processing was impaired (duration comparison and estimation tasks) but not number and space processing. Finding like this are hard to accommodate in ATOM, because if space, time and number representation shared a common magnitude system, then impairment in one domain should correspond to impairment in others domain. Nevertheless, even if important, one single-case study cannot be taken as indisputable source of evidence, especially if it partially contradicts others brain damage studies (See Walsh 2003 for a review). Unfortunately, neurological studies that simultaneously take in consideration spatial, temporal and numerical abilities are few, and often the part of the brain damaged is quite big, and this should prevent from drawing functional and architectural conclusion about neural mechanisms.

Others evidences that challenge ATOM, come from TMS studies. Dormal et al. (2008), compared performance in numerosity and duration estimation after repetitive transcranial magnetic stimulation over the left or right IPS (target areas) or over the vertex (control area). Numerosity processing was impaired only after left-IPS[84] stimulation, but duration judgment wasn't affected neither after the left nor the right IPS stimulation, suggesting that the IPS contribution to magnitude processing is specific for numerosity. Those results are in open contradiction with the study by Alexander, Cowey, and Walsh (2005) that we treated before. Dormal et al. (2008) suggest that this different result using rTMS on the rIPC can be due to the activation of two slightly different brain area in the two experiments (above the angular gyrus & above the supramarginal gyrus) or to task differences. Nevertheless, a recent imaging study support Dormal et al.'s finding: Wencil et al. (2010) did not find any right-IPS activation in a temporal magnitude task in which subject has to compare the duration of subsequent visual stimuli. Similar results (in the sense that right-IPS activation wasn't reported) have been found for duration comparison of looming/receding visual stimuli (Wittman et al. 2010); but see Leewis & Miall, 2003, for a review of studies on temporal perception with or without parietal activation). More studies are needed to specify the functional implication of rIPC in duration judgments.

[84] Bueti & Walsh, errounesly reported that the effect of TMS was observed only after right IPS stimulation (See Bueti&Walsh, 2009)

Moreover, one of the problem that challenge ATOM from the beginning (Walsh, 2003; Bueti & Walsh, 2009) consist in the difficulty to find a comprehensive explanation of the functional role of the left and the right IPS in both symbolic and non-symbolic numerosity processing. Just to give some example, Dormal et al. 2008 found that TMS over the left, but not the right IPS, disrupts numerical tasks. Cappelletti et al. (2007), found that comparisons of both symbolic and non-symbolic numerosity were impaired after rTMS to the left IPS but enhanced by rTMS to the right IPS (see also, Andres et al., 2005). On the other hand, Dormal & Pesenti, (2009) show a common activation of the rIPS (but not the lIPS) between length and non-symbolic numerosity judgment. It is really hard to explain those contradicting findings within ATOM, but not impossible. As Cappelletti et al (2009b) pointed out, the dissociation between numbers and others dimensions (numbers mostly activate the left-IPS, and other dimensions that mostly activate the right-IPS) can be explained referring to the fact that representation of numbers is discrete <u>no matter what stimulus is used</u>, where time, luminance or space, for example, are continuous domains (see also Castelli et al., 2006). Another factor for this discrepancy is the possible confound between parietal activation for numerical processing with parietal activation for response selection. This possibility, suggested at first by Goebel et al (2004) who showed that parietal activation is not number selective when response times[85] are factored out,[86] found further verification in Cappelleti et al. 2010. In this study, people was run in two very similar tasks, one that requested conceptual decision about numbers, and the other that requested conceptual decision on object names. Results showed a higher right parietal activation for conceptual decisions on numbers relative to the same tasks on object name, but the activation of the left parietal cortex was the same in both tasks. Following their findings, the authors suggested that the left parietal number activation reflects a range of processes correlating with RT, including the extraction and comparison of learnt information, highlighting the importance of controlling for task and RTs effects when searching for number selective effects (Cappelletti et al. 2010). Whatever it is the right explanation

[85] And (presumably) response-selection processes associated with changes in RT.
[86] In this study the numerical task was a numerical comparison, and the control task was a line-detection task (detecting the presence of vertical lines between numerical stimuli). It is possible that processing the activation of the line activated the IPS which it’s also involved in visuospatial abilities (See Cohed-kadosh, 2008).

for the implication of the bilateral parietal area in numerical processes, many solicitations make we think that, at present, ATOM cannot account for all those complex interactions (See Cappelletti et al, 2009 for similar conclusions).

Another critics that we can move to ATOM, and that we'll consider more deeply in the section 7.2 of this thesis, is to avoid to consider any significant structural or functional change of the common magnitude metric during the ontogenetic development.[87] For example, Ansari and Dithal (2006; but see also Ansari et al. 2005), revealed that the IPS is recruited for symbolic and non-symbolic numerical magnitude in a different degree according to the age, suggesting that the neurological substrate of basic magnitude processing can change during the ontogenesis. In one of this studies (Asari and Dithal, 2006), for example, fMRI analysis were conducted over adults and children (average age 10) during a non symbolic numerical comparison task. The activation of the left IPS was significantly greater in adults than children for the classic distance effect (Distance X Group interaction for RT, observed in both groups). This results, among others (i.e. Rivera, Reiss, Eckert, and Menon, 2005; Ansari, Garcia, Lucas, Hamon, & Dhital, 2005), led the authors to suggest that even the most basic aspects of numerical cognition are subject to age-related changes in functional neuroanatomy, changes that, if can be extended to others prothetic domains, might be important for a theory of magnitude. Curiously, Ansari and Dithal (2006) don't report any significant activation of the right IPS, during numerical comparison, for the children, when a bilateral significant activation of the IPS is described for the group of adults.

Others empirical evidences that challenge ATOM come from a recent study by Mattheus et al. (in press). They tested the well know effect of others magnitude on subjective duration: stimuli that are brighter, louder, bigger and so on, are judged to last more time than stimuli that are dimmer, softer, smaller and so on (sound frequency: Goldstone, Lhamon, and Sechzer, 1978; Berglund, Berglund, Ekman, & Frankenhaeuser, 1969; Zelkind, 1973; Luminance: Goldstone & Goldfarb, 1964; Goldstone et al., 1978; Xuan, Zhang, He, & Chen, 2007; Vibrotactile stimulation:

[87] The progressive bi-lateralization of the number information processing due to the progressive influence of language to exact number representation could be consider an important exception (Walsh, 2003).

Ekman, Frankenhaeuser, Berglund, & Waszak, 1969; sizes of squares: Thomas & Cantor, 1975; 1976; Xuan et al., 2007; all quoted in Mattheus et al). This effect is predicted by ATOM (2003; 2009) according to the "more A – more B" mapping between magnitudes. Nevertheless, in this study, Mattheus and his collaborators, provide evidences supporting that it is not the absolute magnitude of the stimulus that influence the perceived duration, but the difference between the stimulus and the background for this particular magnitude. So that, bright squares were perceived to last more than dim squares, on a black background, but the reverse happened on a white background. At the same way, loud tones were perceived to last more that soft tones on a quite background but soft tones were judged to be longer on a loud background.[88] The simple mapping "more A – more B" that according to ATOM characterizes the common magnitude system in the human mind, cannot account for those results where the perceived duration increase with the difference between the stimuli and the background:

> "Our results suggest that, if there is a common system for temporal and non-temporal magnitudes, it cannot be based upon an intrinsic association of high magnitudes on one dimension with high magnitudes on another; there must be some flexibility in the representation system and sensitivity to the background against which stimuli occur." (Mattheus et al, 2010, pag 17)

A theory of Magnitude that suggests the presence of a common magnitude metric in the human brain, for which the right IPS is the "primary magnitude cortex"(Bueti & Walsh, 2009), should be able to explain for different activations of the inferior parietal area for temporal, spatial and numerical tasks, for constant dissociation between dimensions in brain damage patients, for a different functional role across magnitudes, inferred by the different effects of trascranial magnetic stimulations, and for cross dimensional interferences that vary relatively to the background in spite of the

[88] This effect is similar to oddball effect described in several studies (i.e., Tse et al. 2004; Pariyadath & Eagleman 2007; Eagleman & Pariyadath, 2009): when a stream of images is shown over and over in succession, an oddball image thrown into the series appears to last for a longer period, although presented for the same physical duration. The oddball image is, as well, different from the given background, and the mechanisms that underlie the oddball effect and the cross-domain interferences described by Matheus et al could be similar.

“more A – more B” mapping. Last but not least, developmental issues should be taken into account.[89]

The impression is that, considering both the first and the last formulation (Walsh, 2003; Bueti & Walsh, 2009), ATOM lacks of specific and differentiated predictions about the relationships between different magnitude dimensions, a clear picture of the shared/distinct cognitive mechanisms and neural substrates that underlie magnitude representations, the different functional role of different brain areas in magnitude processing, and a distinction between continuous/discrete, abstract/concrete and relative/absolute magnitude representations.

In principle, it is possible to say that explain for all the issues displayed above was not the objective of ATOM, especially in the earliest phases of its conception. The variability of the specific mechanisms and structures that underlies magnitude processing founded at different levels of interaction (with different tasks, stimuli, different age-span, level of brain damage, transient contextual factors), doesn’t mean that the theory is wrong. That’s even more fair considering the amount of evidences that are still support ATOM even in its simplest formulation, and that the immaturity of the field (especially in the case of brain imaging and Tms studies) can be one reason of contradicting data (Bueti & Walsh, 2009).

Our goal in these last paragraphs was to present ATOM with his point of force and his contradictions, and show that others alternative explanation for the relationships between time and space in the human mind are not only possible, but even necessary. If this necessity of new theoretical account and empirical evidences will lead to a complete rejection or a slightly modify of ATOM it’s not clear at the moment.

[89] For what it concerns studies in animal behavior, a short review that reports results which are incompatible with ATOM has been provided by Dormal et. Al (2006): “… several studies have challenged the idea of common processes for numerosity and time estimation due to dissimilarities in animal data concerning the shapes of the functions fitting training curves (e.g., linear vs. power functions for numerosity and time discrimination; for a review, see Hobson & Newman, 1981). Secondly, some studies have shown that when animals were able to process the duration and the numerosity of events, they answered on the basis of numerosity only when other parameters (such as duration) were not available, suggesting that numerosity and duration processing may be more dissociated than previously assumed. For example, birds would rather base their choice on the time elapsed than on the number of events occurring during an interval (Lydersen & Crossman, 1974). This tendency was also found with rats in a task using ambiguous stimuli (i.e., with a different answer—left or right lever—for the temporal and numerical dimensions): the rats answered primarily according to the temporal dimension (Breukelaar & Dalrymple-Alford, 1998).” (Dormal et al. 2006, p. 111)

Before restricting the discussion on space and time, and considering the proposal coming from Metaphor Theory, in the next paragraph we'll present some theoretical alternative to ATOM recently proposed by different scholars.

## 6.5 Alternative explanations

One way to explain most of the contradictions carry on by the studies we considered before consists in suggesting the possibility that most of those results (expecially the ones that contradicts each other) are task related effects. This has been proposed as a possible explanation for most of the cross-domain interference asymmetries between dimensions (Bueti & Walsh, 2009; Gobel et al. 2004), a position that we'll consider more deeply later in this work. But, task related effects can also explain for different patterns of neural activation for the same magnitude process (i.e. the activation/non activation of the IPS for temporal estimation or comparison ( see for example, Rao et al. 2001; Mohl and Pfurtscheller, 1991; Harrington, and Haaland, 1991 for activation; and Wencil et al. (2010); Wittmann et al, (2010); for non activation). As Bueti & Walsh pointed out, the parietal cortex, although it may be considered the 'primary magnitude cortex', is only one locus of magnitude processing that is part of a magnitude system in which, for example, magnitude processing also overlaps in the prefrontal cortex both in monkeys and human (Bueti & Walsh, 2009, but see also Walsh, 2003).

> "From the point of view of cortical loci, it is clear that some activation sites for time, space and number overlap and a few do not. This should not be surprising: the architecture activated in any given experiment is highly dependent on the task and one should therefore not expect a single locus to account for all instances of magnitude processing" (Bueti & Walsh, 2009, p. 1833-1834)

The just-partial overlapping of time, space and number area, together with different task-related activation, can be a reasonable explanation for different within-magnitude neural activation. But, apart from don't explaining constant and replicated cross-domain asymmetries and context-dependent cross-domain interferences (that, as explained before, run against the original "mora A-more B" mapping), it shows one more time how the present formulation of ATOM is quite a-specific and in-differentiated, taking the risk to became a trivial description of how space, time, number and other magnitude's processing, put together, create a magnitude system that overlap in many area and share some functions. A picture quite different from the early formulation of ATOM. Until strong evidence of a common metric extensible to all the protethic domains won't be provided, it's  desirable to attempt also other theoretical ways, may be less elegant than ATOM, but that can help to draw a more complex picture of the relationships between magnitude processing in our mind and in our brain.

One alternative proposal, centered on the representations of size and numbers but potentially upgradeable to others magnitudes, has been suggested by Pinel et al. (2004). According to those authors, spatial (size, distance) and numerical magnitude computation shared a common neural substrate (Anterior Horizontal segment IPS) that is different to the neural correlate shared by size and non-spatial domain, such like luminance (posterior IPS and ventral occipito-temporal cortex). In their study, those authors found a number-size and a luminance-size symmetric interference, but a number-luminance asymmetric interference (where number interfered in luminance judgment but not vice versa); moreover, those different behavioral interactions corresponded to different neural activation in fMRI, driving the authors to suggest that the number-size interference originate from different mechanisms than the size-luminace interference:[90]

"The results suggest that during comparative judgments, the relevant continuous quantities are represented in distributed and overlapping neural populations, with number and size engaging a common parietal spatial code, while size and luminance engage shared occipito-temporal perceptual representations." (Pinel et al. 2004, abstract)

[90] But see Choen-Kadosh et al.( 2006; 2008b) for different results and conclusions.

Thus, a categorical and anatomical difference could be made between magnitude that are encoded 'spatially' in the parietal cortex and magnitude that are not.[91] This view suggests that the same mechanisms are not applied to comparison or magnitude judgment for all the prothetic dimensions. Some studies reported by the authors (see Pinel et al, 2004), where different neural activations have been found between number comparison tasks and comparison of ferocity of animals (Thioux et al, 2002), support, in their opinion, this particular cognitive and anatomical distinction.

Another alternative proposal come from Cohen Kadosh et al. (2007; 2008a): different magnitudes can be represented in brain and mind, both by distinct and shared mechanisms, depending on the task request. Evidence for this point of view came from a combined fMRI and ERP study (Cohen-Kadosh et al. 2007). Participant were engaged in a Stroop-like paradigm where judgment of size and numerical value were involved (with the classic paradigm 2/8; 2/8). In the fMRI experiment a region-of-interest (ROI) analysis of the primary motor cortex, revealed interference effect in the hemisphere ipsilateral (irrelevant hand) to the response hand, suggesting that the conflict between numerical and size magnitude is not completely resolved until response initiation. The ERP data confirm the imaging data showing a clear effect in the electrodes above the motor cortex. However, such interaction was found just when the numerical distance between stimuli was big (i.e. 2 – 8; situation that was supposed to correspond to a low cognitive load), but not when the numerical distance was small (i.e. 4 – 6; high cognitive load). In the latter case physical and numerical domains seems to interact only at the comparison stage (as indicated by a P300 peak) and not at the level of response initiation. These findings suggested to the authors that the representation of magnitude is supported by both shared and distinct neural substrate (we should remember here that just number and size mechanisms were tested in this study), and the usage of each mechanism depends on task requirements.

Those data has also been interpreted as supporting the hypothesis that different magnitude are distinctly represented in the brain/mind but can share some mechanisms, like a comparison mechanism (Cappelletti et al. 2009; Cohen-Kadosh et al. 2008a). According to Cappelletti et al. (2009), this (task related) dissociation between numerical

[91] One of the limits of this approach is that we don't know in which category we can put temporal magnitude representations and, either way, a functional explanation of this categorical segregation between spatial and non-spatial magnitude representation is needed.

and size magnitudes in grown-up subjects, and other studies that show infants' different performance with discrete and continuous magnitudes (Huntley-Fenner, Carey, & Solimando, 2002; McCrink & Wynn, 2004; quoted in Cappelletti et al. 2009), can be explained "in terms of a shared comparison mechanism that operates on different magnitude dimensions rather than in terms of a shared magnitude system" (Cappelletti et al., 2009, p. 2744)

A similar alternative to the classic formulation of ATOM has been suggested by Choen-Kadosh and colleagues:

> "…it is [also] possible that the magnitudes themselves are represented in different areas of the brain, depending on the dimension considered, but the IPS hosts a common mechanism involved in processing the comparison between two magnitudes. As all kinds of magnitudes have analogous properties, and presumably their neural codes have analogous properties as well, it is highly possible that the mechanisms operating on these magnitudes are shared across dimensions even if the magnitudes themselves are implemented by distinct neural populations." (Choen-Kadosh et al. 2008a, p. 137)

# 7. Time and Space: symmetry or Asymmetry?

Until now, who have moved critiques against ATOM, has done that mostly referring to the neurological structure that should underlying this common magnitude metric. The data available so far are often contradictory and confused, and it's hard, on this basis, to have a clear opinion about the neurological predictions made by ATOM, or by other similar theories. Curiously, is spite of the modern techniques employed in fMRI and TMS studies, it seems that the most stable and interpretable data are still arriving from the behavioral studies. In fact, if the pattern of neurological activation are often different and hard to interpret in different cases, behavioral studies like the ones presented at the beginning of this chapter give us pretty stable patterns of interference, showing that the relation between different dimension is there, with or without a common neural substrate. As we have seen, interaction between dimensions that can be inferred through behavioral results are pretty clear (see 6.2), but what is important is that regularities between those dimension can tell us more about the relationships themselves. Knowing for example that numerical information usually interferes with temporal judgment, but not vice versa, show a possible asymmetric relationship between number and time that should be explained.

As we noted in the introduction, according to ATOM, space, time and number are symmetrically related. Indeed if they share a common magnitude system they should show cross-domain interaction (as they do) and there is not reason to posit that one dimension should depend asymmetrically on the other.

Nevertheless, the results of the studies that test the interaction between space and time seems to tell us something different. In many studies (Dormal et al. 2006; Casasanto & Boroditsky, 2008; Casasanto et al. 2010) the relationships between space and time appear to be asymmetrical: space interfere with time, more than the other way around.

Bueti & Walsh, in they review of ATOM (2009), seems to be aware that an asymmetrical relation between different dimensions is a potential problem for ATOM. Though, they address the question as this asymmetries founded in many experiment are trivial consequences of the evolutionary function of the magnitude system. This point, as central in this dissertation, deserves a long quotation:

"So far, we have addressed our case that there is a common magnitude system and stated how it is associated with action, but why would we continue to employ common metrics in situations where action is not required? Stavy & Tirosh (2000) detailed many examples of intuitive rules that lead one to make quantitative errors in the absence of any action (although many of them require an understanding of action). More A–more B is one of these rules. We could argue that there is magnitude interference in experiments because of latent action components or some kind of spill over from the magnitude system, but another reason is that they may provide useful heuristics for things that are statistically true about the physical world: faster things do often get further, Usain Bolt, the world's fastest man, does usually have the longest legs in the field, bigger things do usually weigh more.

Thinking about why we have these intuitive mappings may also help to explain why all magnitudes are not created equal. An oversimplistic view of a generalized magnitude system might expect all interference effects to be symmetrical that temporal cues, number, space, luminance and action cues would all impinge on each other. This is clearly not the case. Brown (1997), for example, found that number interfered with time but not vice versa, and Dormal & Pesenti (2007) for example, found that in a modified Stroop paradigm, spatial cues interfered with number processing but number did not interfere with spatial processing." (Bueti & Walsh, 2009, p. 1833)

Why some of these asymmetrical relationships should became trivial *"thinking about why we have these intuitive mappings"* remains unclear, especially thinking about the need of integrate spatial and temporal information in order to make accurate predictions for action. What is most important? Time or space? In which direction should we expect the asymmetry?

Although the asymmetry can be a problem only for an "oversymplistic" view of the theory, the authors try to give two possible explanations for it. The first one:

"Hurewitz et al. (2006) suggested a possible hierarchy of magnitudes from continuous to discrete variables following their finding that amount of stuff interfered with numerosity judgements more than numerosity interfered with 'stuff' (a technical term the literature should embrace)." (Bueti & Walsh, 2009, p. 1833)

It is the case that, sometimes, continuous dimension like space, interferes with discrete dimension (numerosity) more than the other way around (Dormal & Pesenti, 2007; Hurewitz et al. 2006;), but sometimes this relation resulted to be symmetric (Pinel et al. 2004; Kauffman et al. 2005). However, the hierarchical model from the continuous to the discrete domains proposed by the authors, cannot explain for the influence of numbers on duration judgment (Dormal et al. 2006; Olivieri et al. 2008), in which duration usually don't interfere with numerosity judgment (Dormal et al. 2006); and for the space-time asymmetry (Casasanto & Boroditsky, 2008; Casasanto & al. 2010) in which the relationship between two continuous domains is asymmetrical (space influence time more than vice-versa). Hurewitz et al. (2006), compare their results to studies in which infants favored continuous quantities instead of discrete quantities (see for example, Rousselle et al. 2004). Showing that also adults cannot ignore irrelevant size information in making discrete quantity judgment, the author suggested that: even if infants favor continuous quantities over discrete numbers[92] in some experimental paradigms, that does not indicate an inability to represent discrete quantities, but that in these cases the susceptibility to interfering dimensions may be substantial. Anyway, the hierarchical model proposed by Hurewitz et al. is well supported and relevant for a number/size relationship, especially considering the developmental time span. On the other hand, it can hardly be generalized to other magnitudes considering the asymmetries between number and time and space and time.

The second point made by Bueti and Walsh in regard to the asymmetry noticed in several cross-dimension interferences sounds like this:

> "Whether these findings are evidence of constant asymmetries or are task dependent remains to be established" (Bueti & Walsh, 2009, p. 1833)

After an analysis, maybe too much pedantic, one can ask why, if these asymmetries are just task-related effects, their presence is expected (if not predicted) following the intuitive cross-dimensional mapping at the basis of ATOM, and just "*an oversimplistic view of a generalized magnitude system might expect all interference effects to be symmetrical*". Maybe, because asymmetries (especially the space-time

[92] Symilar interesting results have been found with shimps (Boysen et al. 2001)

asymmetry) are not actually predicted by the 'more A-more B' ATOMic mapping, or because both cases (symmetry and asymmetry) will be fine for un-specified reasons. A kind of reasoning, the latter, which makes the theory un-falsifiable, at least for this point. Of course, we cannot answer for the authors, but it seems that this un-falsifiable hypothesis is, at least, explored by them when they say:

> "From the point of view of cortical loci, it is clear that some activation sites for time, space and number overlap and a few do not. This should not be surprising: the architecture activated in any given experiment is highly dependent on the task and one should therefore not expect a single locus to account for all instances of magnitude processing" (Bueti & Walsh, 2009, p. 1834)

A broad interpretation of this statement could be that, paradoxically, even a clear double dissociation for space and time processing in two areas, both different of the IPS, would not falsify the theory, because it can be interpreted as an evidence that the magnitude system is just partially shared, and it's independent in some other parts. That's can be true, of course, but it should be more specific in order to allow some falsification.

We truly think that the supporters of ATOM situate themselves somewhere in the middle between an oversimplistic, rigid interpretation, and an un-falsifiable flexibility of the theory. In waiting that ATOM grow up healthy and strong, we will assume that a symmetric relationship between prothetic dimensions, and especially space and time, is implicit in ATOM, and we will argue against it. We will provide a review of the principal studies that suggest that space and time are asymmetrically related in human mind, and we will provide new evidence which tend to exclude that the space-time asymmetry is a task artifact.

## 7.1 A space of time

As we have seen thoroughly in the fist session of this thesis, according to the 'metaphor theory', a great part of our conceptualization of time is metaphoric (the rest is metonymic), based on a conceptual mapping from the source domain SPACE to the target domain TIME. The relationship between space and time is asymmetric, as well as many others relations Source/Target, where part of the conceptual structure of the more concrete domain is recycled to in-form, in the sense of 'give form', the more abstract domain. The asymmetry is really clear in language, not only in terms of frequency (we use spatial metaphors to talk about time much more that temporal metaphors to talk about space), but also considering how obligatory these metaphors are: if we can easily talk about space without using temporal metaphors, we can hardly talk about time avoiding spatial metaphors (Jackendoff, 1983; Pinker, 1997; Casasanto & Boroditsky, 2008). Moreover, pattern in historical change in the etymology of temporal words (see 5.2.2) and studies on children language acquisition (Clark, 1973), strongly support the functional and temporal primacy of spatial compared to temporal language. But these theoretical and linguistic evidences are probably not enough to convince everybody (especially psychologist or cognitive scientists) that the way we talk about space and time reflect the way we think about them (Murphy, 1996, 1997; Gibbs, 1996; Pinker, 2007).

The first empirical evidences for an asymmetrical relationship between space and time in human cognition, as predicted by the theory of cognitive linguistics, come from a recent experiment by Lera Boroditsky (2000). In this paper, Boroditsky proposed what she called the Metaphoric Structuring View (MSV), a theory derived by Lakoff & Johnson's Metaphor Theory (MT) but that can be evaluated independently (Boroditsky, 2000). This new theoretical frame was needed, according to Boroditsky, because the MT lacks the detail of a specific psychological model making hard to extract a single testable statement of the theory. In particular, the aim of this important paper that, we should say, started a fruitful sub-field of studies in cognitive psychology, was threefold:

1) to propose one detailed account of how abstract concepts are learned, represented, and reasoned about.

2) to provide psychological evidence in support of this proposal.

3) to show that the current evidence is not consistent with a plausible non-metaphoric account.

At the basis of the MSV there is the belief that metaphors provide relational structure to those domains where the structure may not be obvious from world experience. The mechanism to construct metaphorical abstract domain should be similar, then, the mechanism used to understand analogies (Gentner & Wolff, 1997), and it has been tested by Boroditsky on the domain of time.

The study was centered on two different ways to represent temporal succession metaphorically, the 'ego moving' and the 'time moving' schema (Clark, 1973; Lakoff & Johnson, 1999). As we have already seen, the ego-moving schema is well represented in expressions like "we passed the deadline", for which we can assume that the observer progress along a fixed time line toward the future; the moving-time schema is represented in English by sentences like "the deadline has passed", a representation in which the observer is stationary and the time, conceived as a sort of river composed by the different events, is moving toward the observer itself, with the future event behind the most recent events (See p. 5.2 and 5.2.4 for a deeper description of these two schemas). The aim of Boroditsky was to test the psychological reality of those two schema of time suggested by the English everyday language, and find evidence that those schema are metaphorical constructed upon different spatial representation of spatial perspective (i.e. I move through different things/different things move toward me).

In experiment 1 the target question was an ambiguous temporal question like "*The meeting originally scheduled for next Wednesday has been moved forward two days. When is the meeting?*" This is an ambiguous question in English that can be interpreted in different ways and yield to different answers according to the schema used to understand the question. According to the ego-moving schema the meeting is now on Friday, but according to the time moving schema the meeting is now on Monday. In this first study people were primed with two different scenarios, either a spatial "ego moving frame of reference" (spatial source to the temporal "ego moving" frame) or a spatial "object moving frame of reference" (analog to the "time moving" frame, see fig. 9)

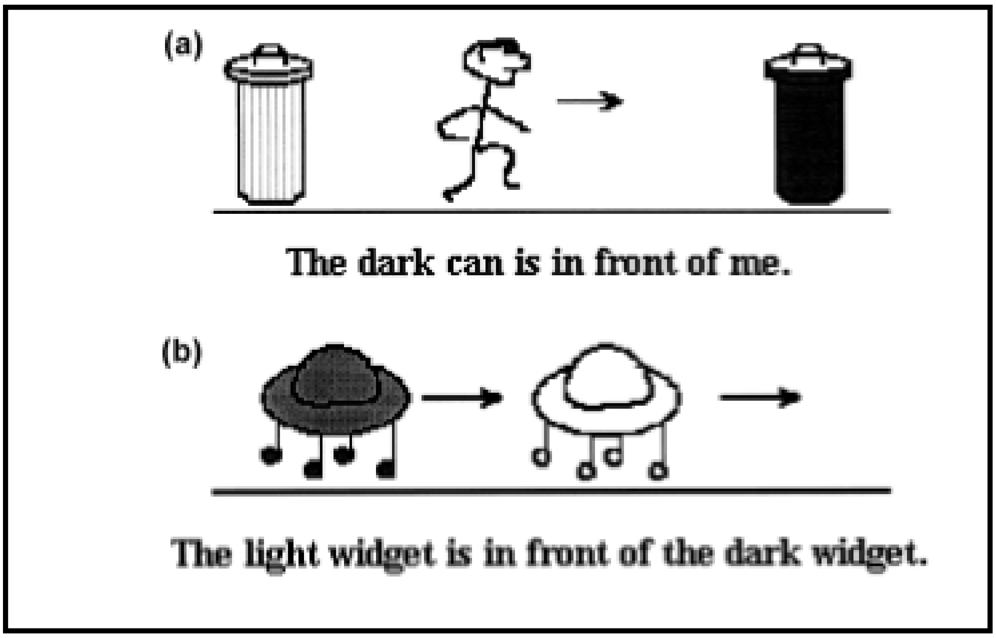



Fig 9. (a) Sample ego-moving scenario used as a spatial prime in Experiment 1. (b) Sample object- moving scenario used as a spatial prime in Experiment 1.

Participant completed a pencil and paper questionnaire where either ego-moving scenarios or object-moving scenarios (among other irrelevant items) preceded the target question (i.e. the moving-meeting question). Subjects that had a ego-moving spatial priming were more likely (73,3%) to answer the target question using a ego-moving temporal schema (saying that the meeting were moved on Friday), and subject primed with the object-moving scenario were more likely (69,2%) to use a time-moving schema (meeting on Monday).

This finding confirmed that the domains of space and time interact at the level of conceptual structures, and not just in language, but it wasn't enough to conclude that the temporal conceptual structure were derived metaphorically from the more concrete spatial conceptual structure. One alternative, among others, can be that both temporal and spatial structure activate a more general abstract representation, or that time and space are represented independently in mind, but they have a very similar structure (Structural Similarity, Murphy 1996 ). So that they can prime each other and, according to this view, metaphorical language arises when people notice pre-existing structural similarities between domains. To disentangle these puzzles, in experiment 2 and 3, Boroditsky tested both the effect of space on time and the effect of time on space using both questionnaires and reaction-time measurement. Moreover, also within domain priming ('time to time' and 'space to space') has been tested. Results showed that temporal priming influence temporal judgment and spatial priming influence spatial judgment. Looking at the cross-domain comparison, though, just spatial primes influence temporal judgment (as in experiment 1), but temporal primes didn't have any effect on spatial judgment. This asymmetrical pattern of interaction between spatial and temporal thinking it's consistent with the directionality in metaphorical language described in Metaphor Theory. Directionality that it's hard to explain according to other theoretical frameworks (e.g. Structural Symilarity or ATOM).

These results are good evidence for the psychological 'reality' of the mental metaphors for temporal thought, but, a question we may ask is: do people use mental representations of space in order to mentally represent time, as metaphors in language suggest they do, even when they're not using language? This possibility, proposed by Casasanto (Casasanto, 2005; Casasanto & Boroditsky 2008) suggests that participants in the previous experiments may have shown these relations between spatial and temporal thinking (consistent with linguistic metaphors) only because they were required to process space or time *in language.* As Dan Slobin pointed out, when people are "thinking for speaking" (and, presumably for reading) grammatical features and other peculiarity of their spoken language could structure and shape their intellectual process in a way that can be different from similar intellectual processes that take place when people are involved in a non-linguistic mental activity (Slobin, 1996). Shortly, the linguistic nature of the task proposed by Boroditsky can be responsible for the metaphorical patterns of thought detected on the experiments. What happens if participants are tested on nonlinguistic tasks?

To find out, Casasanto & Boroditsky (2008), showed to MIT undergraduate students lines of various spatial lengths that appeared on a screen for varying durations (Casasanto & Boroditsky, 2008). They were asked to estimate either the duration or the spatial length of each line, using mouse clicks. After each line, if the participants saw an hourglass appear on the screen they estimated the duration of the previous line by clicking on the center of the hourglass, waiting the correct amount of time and then click again. If a "X" appear on the screen after the line they had to estimate the length of the line by clicking once on the center of the X, move the mouse horizontally toward the right, and click again when the correct distance were reached (the structure of the experiment is summarized in Fig. 10).

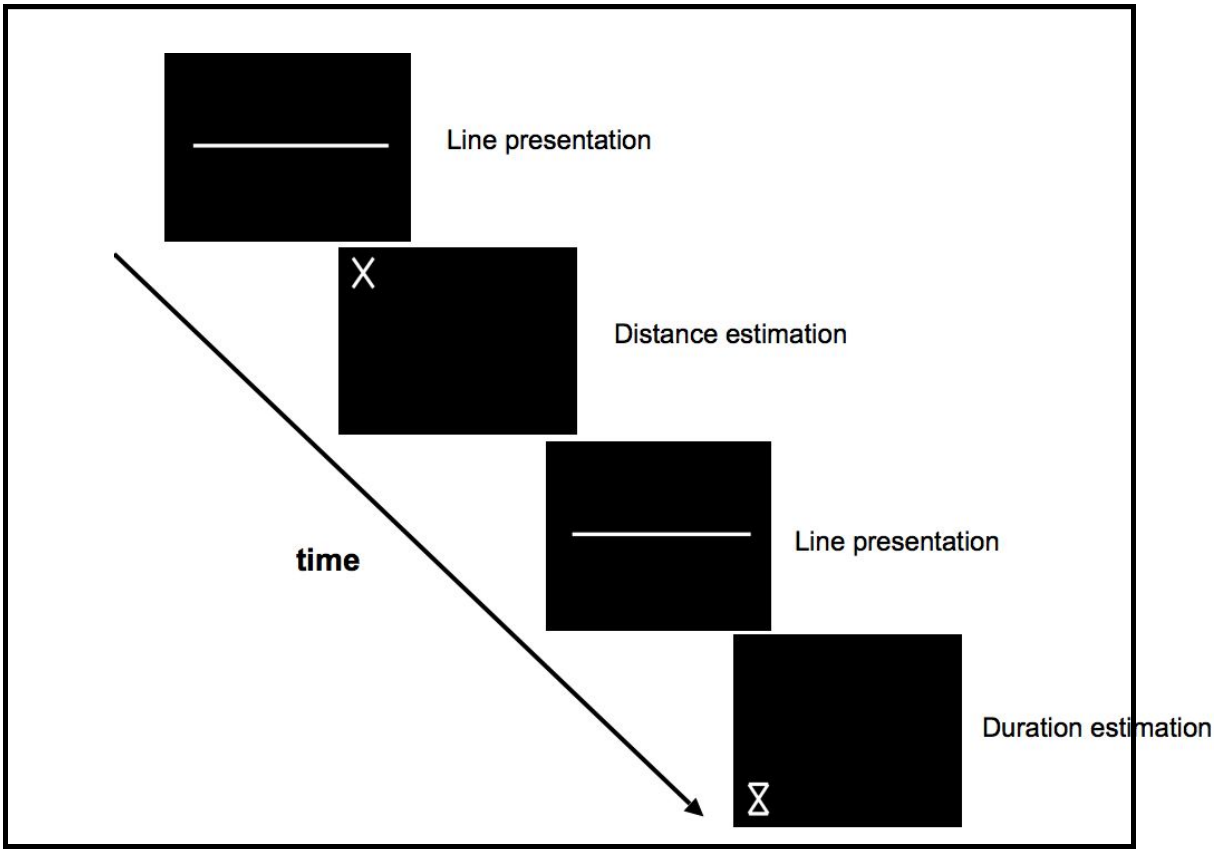



Fig. 10: After each line participant were asked to estimate either the length ("X") or the duration (Hourglass) of the line. Nine different length (from 200 to 800 pixels) were fully crossed with nine different durations (from 1000 to 5000 milliseconds) to create 81 trials that were randomly presented on the screen. Each line appear twice, one for duration and one for length estimation.

Participants were unable to ignore irrelevant spatial information when making judgments about duration, but not the converse. For stimuli of the same average duration, lines that extended shorter in space were judged to take a shorter time, and lines that extended longer in space were judged to take a longer time. By contrast, for stimuli of the same average spatial length, spatial estimation was not affected by the line's duration (Fig. 11). This cross-dimensional asymmetry, predicted based on patterns in language, was shown here in non-linguistic psychophysical judgments.

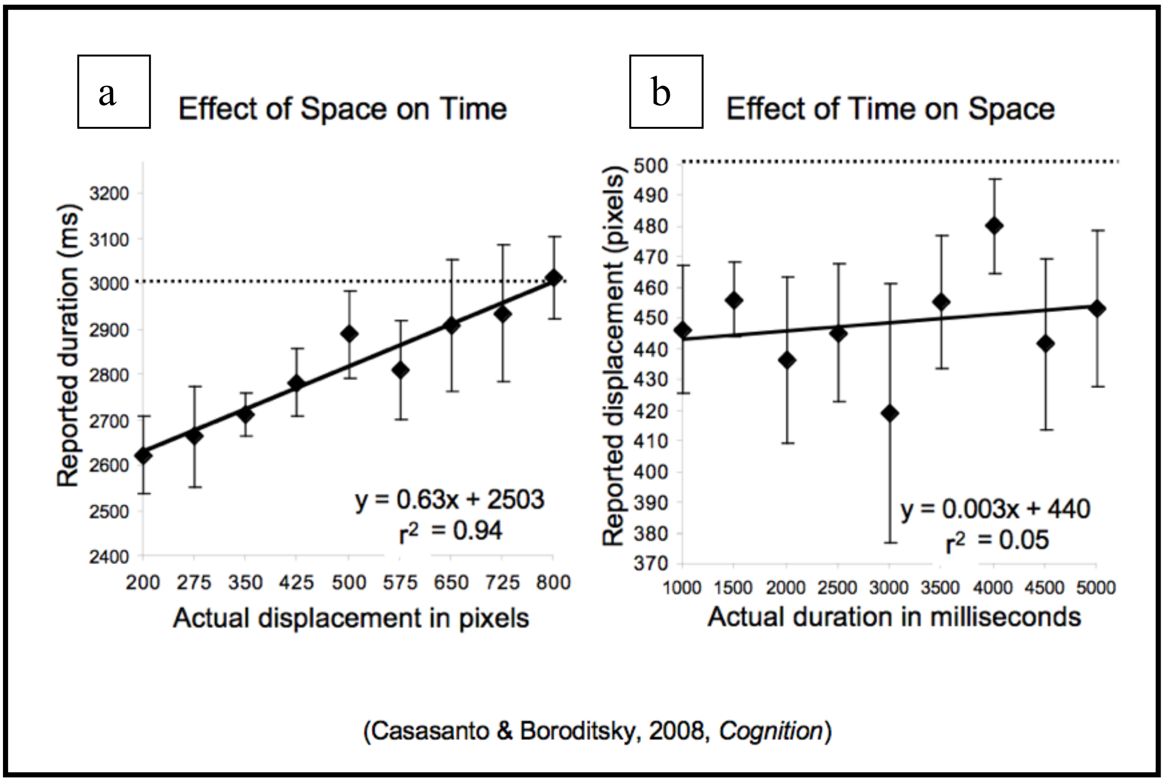



Fig 11: a) Effect of the spatial length of the line on duration estimation. Longer lines (in pixels) were estimated to stay on the screen for a longer time. b) Effect of the duration of the line on space estimation. The duration of the line do not effect the estimation of the spatial length.

Five follow-up experiments have been done. In one, for example, attention were alternately directed over the spatial or the temporal dimension warning the participants, before each line, if they had to estimate time or space. In others experiment the lines were stationary (instead of growing, so that effect of movement were excluded), or were substituted with a moving dot (so that the spatial interval could be never seen all at once), or accompanied with a co-occurent tone (so that time could be perceived in two different ways, visual and auditorial), or a temporal frame were added (to match the spatial frame provided to the monitor of the computer).

In all those cases results did not change, as predicted by metaphorical patterns in language, space influence time more than the other way around. These results, especially because obtained in using a psychophysical methodology, challenge the symmetrical view implicit in ATOM. Nevertheless, one can ask: since we learn to associate metaphorically space and time through the experience (Lakoff & Johnson, 1999; Casasanto, 2008), it is possible that temporal and spatial thinking are originally symmetrically related in our mind, and become asymmetric during the psychological development through our acculturated experience of the world. Casasanto and colleagues (Casasanto et al. 2010), tried to give an answer to this question testing children in an adapted version of the ‘growing lines experiment just described. An experiment similar to the one done by Piaget and described in 5.2.3. In this study children of different ages (from 4 to 11 y.o.) watched some short movie in which two cartoon snails were travelling in parallel path in the same direction (Fig. 12). There were three different types of movie: 1) the two snails travel for different space and different time; 2) the two snails travelled for different space but for the same time; 3) the two snails travelled for the same space but for different time. The children had to answer to two kinds of questions in two different sessions. In the spatial session the experimenter asked the children: 1-“*Did the two snails stop at the same place?*”; 2- “*Did one of the snails go farther? Which one of the two?*”.

In the temporal session, the questions were: 1- “*Did the two snails stop at the same time?*”; 2- “*Did one of the snails move for a longer time? Which one?*”. Each child watched the three videos twice, in each session, for a total of 12 trials.

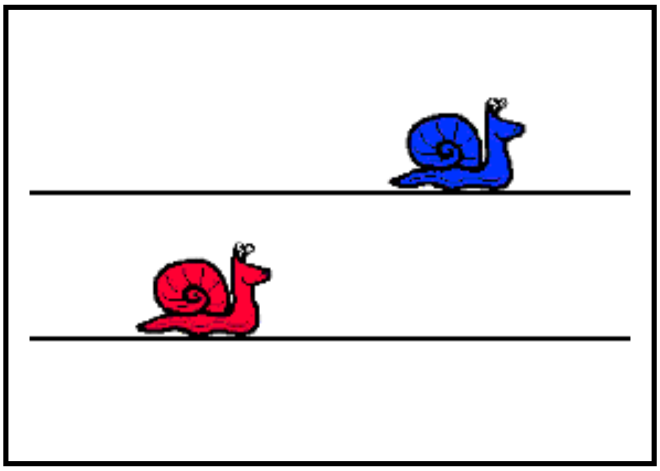


Fig12: The snails game. Cross-dimensional task.

The experimenter wanted to test if the children were influenced by the irrelevant spatial information (i.e. final position of the two snails) when they were making temporal judgment, and, vice versa, if the irrelevant temporal information (longer/shorter movement) could influence their spatial judgment.

Two between subjects factors were included in the design. The children were separated in ‘younger’ (4-6 y.o.) and ‘older’ (9-11 y.o.), and, across age, the children were assigned to the ‘distance wording’ or the ‘non distance wording condition’. In the distance wording condition, the children received the question displayed above. In the ‘no distance wording condition’ the questions were different: instead of the adverbial ‘longer’ were use the quantifier ‘more’, (i.e. ‘did one of the snails move for more time?’). Of course in English sounds weird the expression ‘more time’, and it’s really rare, but design those two different type of task were important in order to be able to distinguish task were a metaphorical 'distance' word were used (i.e. 'longer time'), from task were metaphorical distance were not used (i.e. 'more time'). The prediction were that the interference from space to time were stronger when metaphorical distance were used. Last comment, in order to avoid the sense of weirdness due to the use of the quantifier 'more' referring to temporal intervals, the experiment has been done in Greece, with Greek-speaker children. In fact, in Greek, both 'distance metaphors' and 'amount quantifiers' can be used to talk about time (we will talk about the peculiarity and importance of the Greek temporal expressions in the last chapter of this thesis).

Two control tasks, where the children had to compare the spatial length of two colored lines or the duration of two bouncing snails, complete the experimental design. The control tasks tested if the children were able to make spatial and temporal judgment independently, without the interference of the other dimension.

The results show that participant were un-able to ignore the irrelevant spatial information when they were making a temporal judgment, saying, for example, that the snail that moved for a longer space also moved for a longer time, even if it wasn't true. On the other hand, children were far less confused by the temporal information in making spatial judgment (Fig 11). Moreover, no significant difference has been found between the 'distance wording' and the 'no distance wording' version of the game, proving that processing on-line linguistic distance metaphors for time it's not the cause of the cross-dimensional interference.

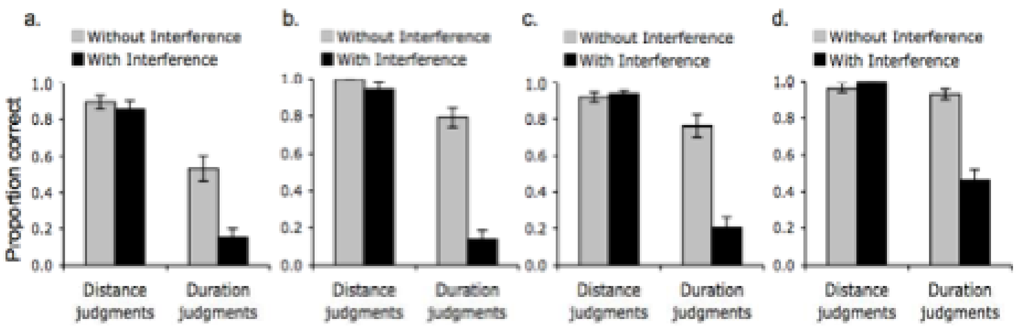



Fig 12: Proportion of correct distance and duration responses in each group of participants. (a) Younger children, Distance wording. (b) Younger children, No Distance Wording. (c) Older children, Distance Wording. (d) Older children, No Distance Wording. The istograms indicate the proportion of correct responses in the control tasks (without interference) and the cross-domain task (with interference). In all the 4 conditions, the proportion of correct responses doesn't change between the with- and without- interference condition for the spatial estimation task. On the other hand, the same proportion is significantly different between the with- and without- interference condition for the temporal estimation task, showing that irrelevant spatial information interfere with temporal judgment, more that vice versa. Error bars indicate standard error medium (s.e.m.).

These results strongly suggest that in children, at least from the age of four, the relationship between temporal and spatial reasoning is asymmetrical: space influence time more than vice-versa. A result that again support the metaphorical view and challenge ATOM. Nevertheless, nothing we can say about the spatio-temporal thinking in younger infants and babies. Indeed, a 4 years old child has already had a lot of experience with the spatial and temporal aspect of the world and its related actions and thoughts. Therefore, the fact that he shows a pretty clear space-time asymmetry doesn't rule out the possibility that the relation between space and time in our mind started out symmetrical, and become asymmetrical through the ontogeny (Arguably under metaphorical construction based on the interaction with what we call the outside world; see Lakoff & Johnson, 1999; Casasanto, 2008a,b,c; Bottini & Kuijstern 2010).

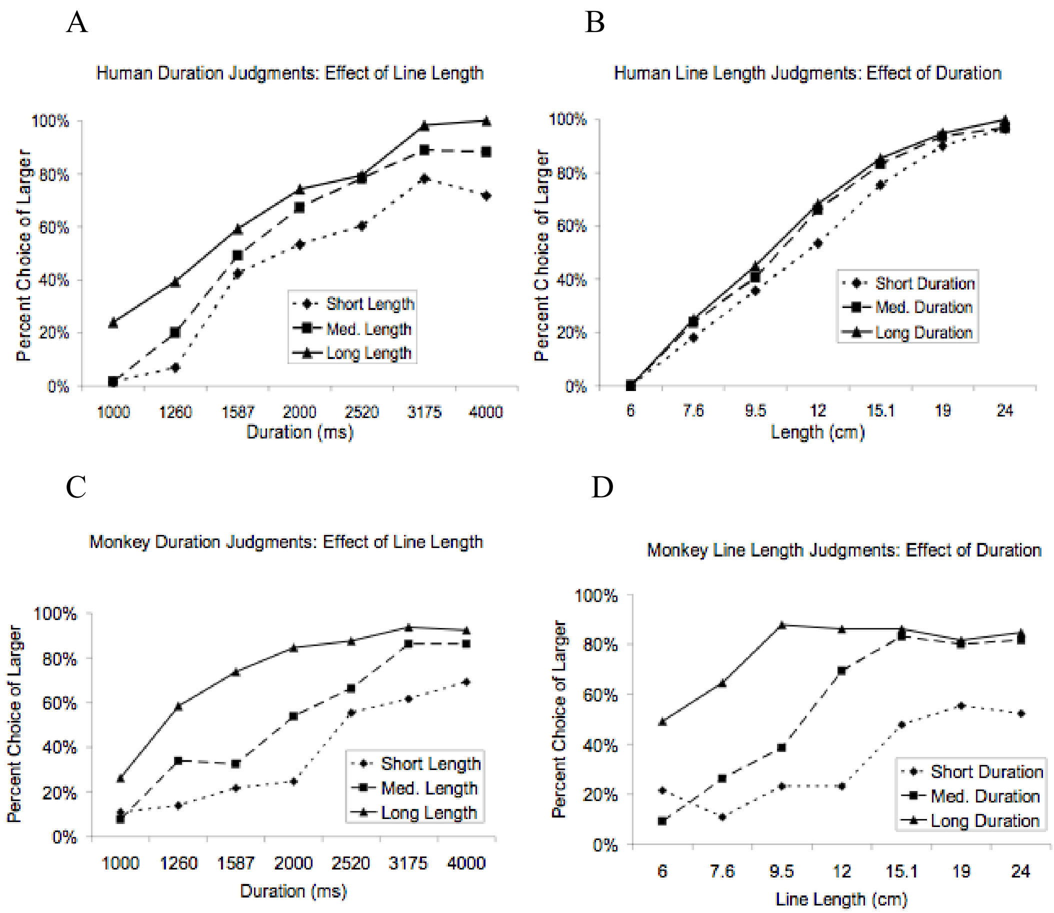
The hypothesis that our understanding of space and time can be 'ATOMic' at the early age, and become metaphoric later is a possibility that we consider seriously, given, among other reasons, the experiential basis of the Metaphor Theory. At the moment, we think there is a lack of clear evidence that can support one of the two claim. However, more or less indirect evidences have been provided to support either one or the other view. We will consider those studies in the last part of this paragraph. Now, we have to talk about monkeys.

Since the relationship between space and time has been found to be asymmetric both for grown-ups and children, it could be interesting to know if the same asymmetry can be found in non-human animals, especially in monkeys, in order to be able to hypothesize, in case, a phylogenetic development of, either the asymmetry itself, or the cognitive machinery which allow to understand and represent a conceptual domain in terms of another on the basis of the experience. To find out, Merrit, Casasanto & Brannon (2010), studies the relation between spatial and temporal behavior in rhesus monkeys. The authors designed a non-linguistic bisection task, whose instruction could be learned by trials and errors in a practice session. Thus, no verbal instruction was necessary. Humans subjects and rhesus monkeys perform the experiment which basically consisted in classifying as short or long (in time or space) steady lines that appeared on a touch screen. The lines has different durations and different spatial length, and the authors wanted to see if the irrelevant dimension could influence the judgment on the relevant dimension (like the others psychophysical experiments described above). Humans subjects shows the classic asymmetrical pattern in which, the temporal bisection judgment (i.e. to decide if the line were long or short, in time, according to a standard learned on the practice session) were influenced by the irrelevant spatial length of the line, so that, for lines with the same average duration, spatially longer lines were more likely judged to be "long" in time, and spatially shorter lines to be "short", in time. On the other hand, the irrelevant duration of the lines, during the spatial judgment, could be easily ignored by the participants.

A different pattern has been found for the rhesus. The two monkeys that have been tested in this experiment showed a symmetrical pattern: (task-irrelevant) space influence time estimation as (task-irrelevant) time influence space estimation (fig. 13). The authors concluded:

> "The asymmetric relationship we find in humans supports theories of metaphorical mental representation, according to which abstract domains like time are structured, in part, by mappings from more concrete domains like space. By contrast, the symmetric relationship in monkeys is most consistent with ATOM, which suggests that space and time are represented by a common metric for analog magnitudes. Together, these data raise the possibility that the capacity to represent abstract magnitudes metaphorically may be uniquely human." (Merrit et al. 2010)

The origin of this difference is impossible to guess at the moment. Of course, the first explanation that comes to mind is that this is an effect of language. The asymmetrical – and therefore metaphorical – nature of our representations of space and time is due to the effect of linguistic patterns learned by linguistic interaction with other human beings (Srinivasan & Carey, 2010). Of course, for a psychologist, and not only maybe, the first and most important difference between us and our most close evolutionary ancestors, so monkeys, is the capacity of language.




Merrit, Casasanto & Brannon, 2010, *Cognition*

Fig. 13: A) Significant effect of the irrelevant spatial dimension on the duration estimation for human subjects; B) Non significant effect of the irrelevant temporal dimension on the spatial estimation for human subjects; C) Significant effect of the irrelevant spatial dimension on the duration estimation for rhesus monkeys; B) Significant effect of the irrelevant temporal dimension on the spatial estimation for rhesus monkeys; The cross dimensional effect was determined calculating the shift of the Point of Subjective Equality (PSE), the point in which the value (spatial or temporal) was equally likely to be classified as long or short.

And it's easy to attribute to this enormous difference all the other psychological or behavioral differences that we can found between us and them. In the light of these data, we cannot rule out the possibility that linguistic interactions are responsible for the human space-time asymmetry, but, as Merritt and colleagues clearly pointed out:

"If the monkeys had shown a similar space- time asymmetry to humans, this would have provided an existence proof that mental metaphors can develop in a mind without language. But importantly, the fact that monkeys showed a different pattern from humans does not license the opposite conclusion; we cannot conclude that language is necessary for the development of mental metaphors from space to time. It is possible that space-time relationships in monkeys and humans differed because of language-related differences, but it is also possible that they differed due to any of the myriad bodily differences between species that constrain the way we interact with the physical environment." (Merrit et al. 2010)

The role of language on the metaphorical construction of temporal concept is indeed a fascinating topic that we'll address more deeply in the last part of this thesis. For the moment it is enough to ascertain that the relation between space and time in monkeys' mind, inferred by behavioral data from a nonlinguistic interference paradigm, support ATOM. These data, altogether with previous neurological data showing an overlapping populations of magnitude neurons in homologous regions of monkey cortex (Thompson et al, 1970; Sawamura, H. et al 2002; Nieder et al, 2002; Onoe et al. 2001; Leon & Shadlen, 2003), support the evolutionary primacy of a symmetric relationship between space and time. Therefore, our questions return to the ontogenesis: what about human babies? Is this relationship still symmetrical in newborn and very young children?

Following a recent study by Lourenco and Longo, the answer seems to be "yes".

Lourenco and Longo (2010) recently provided evidence that 9 months old babies are able to transfer associative learning across magnitude dimensions. The paradigm used in the study was modeled on the task used by Meck and Church (1983) to study the transfer of associative learning across time and numerosity in rats. Here, the domains investigated by the authors were three: space, duration and numerosity. In this experiment, infants were trained to associate a specific color-pattern to a high or low magnitude along a single dimension. For example, within space, the larger objects were black and had stripes, the smaller objects were white and had dots. After the training, similar objects with the same color-pattern mapping were presented to the baby. In this session, however, the magnitude of another dimension (i.e. time) was manipulated. If the babies were able to transfer the association learned in one domain (e.g. big size = black with stripes, small size = white with dots) to another domain (e.g. long duration =

black with stripes, short duration = white with dots), they should spend more time[93] looking at the object for which the new pattern-time association is incongruent to the old pattern-space, association (see table 1 for a summary of the possible congruent and incongruent conditions across dimensions). This is exactly what they found. This result supports theories of an early-developing and pre-linguistic general magnitude system which allows cross-domain symmetric interaction and generalization ('more A – more B') as predicted by ATOM. Thus, in this study, color/pattern-magnitude association could be transferred (generalized) symmetrically from the spatial domain to the temporal domain and from the temporal domain to the spatial domain. This symmetrical relationship could lead us to the conclusion that space-time concepts begin in each human's mind as ATOMic and become metaphorical later. This point of view is also supported by studies that demonstrate that 6-month-old babies show difference-discrimination thresholds at the same ratio (i.e. 1:2 but not 2:3) for size (Brannon, Lutz, & Cordes, 2006), numerosity (Xu & Spelke, 2000) and duration (van Marle & Wynn, 2006).

| | **Direction 1** | **Direction 2** |
|---|---|---|
| **Size-Numerosity** | Size-to-numerosity | Numerosity-to-size |
| **Size-Duration** | Size-to-duration | Duration-to size |
| **Numerosity-Duration** | Numerosity-to-duration | Duration-to-numerosity |

Tab 1: The table show all the 6 between subject condition. Children were able to generalize the color/pattern-magnitude mapping learn in one dimension (i.e. size) to another dimension (size-to-duration) and vice versa (duration-to-size). The within subject factor was congruity, subjects look more to incongruent trial that to congruent trial even if they were trained in one dimension and tested in another.

Are these results clear evidence that representation of time and space are symmetrically related in the babies mind? Our answer is that they are not. Leaving aside, for the moment, ATOM and the existence or not of a common magnitude system shared across prothetic dimensions, we can suggest some reasons why Lourenco & Longo's study cannot be taken as a sound proof of a symmetrical space-time interaction

93 Babies were tested with a preferential looking paradigm

in babies' mind. In principle, it is possible that an asymmetrical space-time association is present from the beginning in the child's mind (a possibility that runs against the experiential basis of the metaphor theory), or that it is built up on the basis of very early interactions (before 9 months), but this asymmetry is not detected by the generalization paradigm used by Lourenco and Longo. In fact, space and time might still share the same magnitude metric even if the nature of this common metric is inherently spatial; in this case, it should not be surprising that it is possible to make generalizations between the two linked domains. If space and time are somehow linked in our mind, it is reasonable to expect that previous temporal information can give rise to certain expectations about subsequent spatial information, and vice versa. Even if our temporal representations depend on space more that the converse. We want to make this point clear. Assuming that time and space are somehow linked in our mind, after repetitive exposure to a time-color mapping (more-blue/less-red), we would be more surprised to see, afterward, in the same environment, a reversed space-color mapping (less-blue/more-red) that a congruent space-color mapping (more-blue/less-red). And this situation is predicted both by a symmetrical space-time relationship and by an asymmetrical one. Of course, in the latter case, it could be that the expectation (prediction) created from space to time is stronger than the expectation created from time to space, in other words the surprise should be bigger in one case than another. But it doesn't have to be. Indeed, a succession of congruent mappings is always less surprising than a succession of incongruent ones, independently of the kind (symmetric-asymmetric) of relation between the two dimensions. We might say that the *looking-time* measures the 'degree of surprise' (novelty) of a stimulus, relatively to an expectation based on repetitive exposure to previous stimuli. But it is possible that the 'degree of surprise' or 'preference-for-novelty test' it is not a good index of the type of relationship between two factor (even if it's a good index to test if there is any relationship between two factors). Indeed, the 'degree of surprise' is the only thing that is measured here, because babies do not have to perform any task.[94] Let's explain this

[94] For example, also in Boroditsky 2000 (exp. 3) the paradigm used involved the congruent or incongruent succession of spatial and temporal association, with the result that switching from space to time has a different cost than switching from time to space (measured by the RT). But, in this case, subjects had to perform a spatial or temporal judgment, meaning that they had to

with a metaphor: We know that the level of mercury in a thermometer depends on the temperature in the room, but the temperature in the room doesn't depend on the level of the mercury in the thermometer. Consider two situations, you feel just fine in the room and 1) You check the timer of the heating and it's going at the maximum power from 3 hours, then you check the thermometer and it's signing 0°C; or 2) you check the thermometer and it's signing 0°C, then you check the timer of the heating ad it's going at the maximum power from 3 hours. After which of these two double-checking would you feel more surprised? Hard to say.

This is just a metaphor, and does not pretend to have any explanatory power, but we hope it's useful to understand that it is possible that the same expectation is created from space to time, and from time to space, even if time depend on space more than the other way around. Thus, the paradigm used by Lourenco & Longo is a good paradigm to investigate if two or more dimensions are linked, but not so good to investigate the nature of this relationship.

For this reason, we suggest that an interference paradigm, used to test the space time asymmetry in adults (Casasanto, 2008) and children (Casasanto et al. 2010), is still the best test to investigate if the space-time relationship is symmetric or asymmetric.

Another reason to prefer this kind of paradigm is that in a Stroop-like test the two dimensions are presented simultaneously and the coupling can be congruent or incongruent. Processing the two dimensions simultaneously, especially in the incongruent condition, should cause a competition for cognitive resources (within magnitude processing, between dimensions), and the more basic dimension should be advantaged. Presenting the two dimensions one after the other, as in Lourenco & Longo (2010), allow the distribution of the same resources (if needed) between domains. Moreover, usually in the Stroop-like paradigm an explicit judgment or choice is required (i.e. 'more than-'/'less than-' judgment) making easier to check the reciprocal

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engage in cognitive processing which can be faster or slower (facilitated or not) if the switch goes from the basic to the derived dimension or vice-versa. For this reason, we think, Teusher et al. (2008) have failed to find space-time asymmetry in ERP measures in their congruity detection paradigm: subjects had just to assist to congruent and incongruent sentence-picture succession, without being engaged in any task.

influence between dimensions when the dependent variable (the speed or the accuracy of the judgment) is measured. Of course have 9 months babies making explicit judgment is quite hard, but, also the looking-time, if combined with a Stroop paradigm, can be a good dependent variable.

To sum up, although multiple lines of evidence suggest that spatial and temporal thinking relate to each other symmetrically in the mind of the young child (Merrit & al. 2010; Lourenco & Longo, 2010; Brannon, Lutz, & Cordes, 2006; van Marle & Wynn, 2006), these studies are not sufficient to rule out the possibility that space and time representation are asymmetrically linked from birth. Thus, more studies have to be done in this direction. Finding symmetrical space-time connections in babies would be consistent with an experience-based theory of mental metaphors (Lakoff & Johnson 1980, 1999; Boroditsky 2000; Casasanto 2008), for which the space-time ralation is initially symmetric and become asymmetric through a progressive, experience-based, metaphorical mapping. On the other hand, the hypothesis of an innate space-time asymmetry is plausible but hard to be empirically investigated. In fact, even if asymmetrical interaction between temporal and spatial thinking or behavior is detected in very young children, it is really hard to test '0 days old' children whit no experience of the physical world. For the moment, this problem requires a philosophic more than a scientific explanation. The same problem, in principle, is attributable to a point of view, like ATOM, for which the space-time relation is innate but symmetric. In fact, considering the evidences of a space-time asymmetry in adults and children, and accepting a space-time symmetry in babies, a radical experience-based theory could say that a symmetric conceptual relationship between space and time is built-up very early, through the experience that space and time are strictly correlated in the physical world, and it is continuously shaped by the later-on experience till becoming asymmetric. Using Lakoff & Johnson's terms, we could say that the child goes through a period of conflation, in which the source and the target domain are associated and are metonymically interchangeable in certain situations (e.g. perception of motion), until a stable asymmetric metaphorical relationship is established.

On the other hand, a view that will reconcile Metaphor Theory with ATOM could say that space and time are structurally and functionally symmetrically linked from the birth, because this link has became hardwired in our mind and brain through biological evolution (as the study with animal and especially monkey could suggest). Later in the personal development, under the influence of sensory-motor experience and cultural factors, this relationship could become asymmetrical, through metaphorical mapping between the source domain SPACE and the target domain TIME.

A similar hypothesis has been recently suggested by Srinivasan & Carey (2010). They presented both to adults and 9-months babies couple of contributory lines and tones. In one case, the coupling was congruent, so that a long line (in space) corresponded to a long tone (in time). In the other case, the coupling was incongruent, so that to a long line corresponded a short tone, and vice versa. In a later memory test, participants more accurately remembered the congruent pairings than the incongruent ones, showing a preference for a "more-to-more" congruent mapping than a "more-to-less" incongruent one. However, in a subsequent test in which the two dimensions coupled together were space and loudness, instead of space and time, participants' performance was the same both for congruent and incongruent pairings.[95] Srinivasan & Carey suggest that representations of length and duration functionally overlap more than representations of length and loudness. If loudness and space (length) show structural similarities (they are both *prothetic* dimensions), space and time are not only structurally similar, but they have a stronger relationship – a *functional overlap* – that allows these representations to automatically engage one another. This study suggests that the relationship between space and time is functional – not only structural, as is the relation between loudness and space. This result could be reconciled with ATOM suggesting the hypothesis that space and time could have a functional relation because, according to Walsh, the general magnitude system finds its evolutionary roots in the need of combine spatial and temporal information for motor action planning. A functional interaction should not exist between other dimensions (like loudness) that became part of the general magnitude system in a subsequent stage of the evolution (but, the others prothetic dimensions should show structural cross-domain interactions). However, such a theory is presented here as a speculative option.

[95] For 9-months babies the lines were substituted by cartoon caterpillar, and a preferential looking paradigm was used (see Srinivasan & Carey, 2010 for more information)

Srinivasan & Carey suggest that functional overlapping between space and time do not need to be constructed through sensory-motor experience that allow structural mapping from the more concrete to the more abstract domain (Lakoff & Johnson, 1999; Casasanto, 2008) but could be due to an innate functional overlap between these representations, which is the product of an evolutionary exactation of spatial computational and neurological structure for temporal understanding and thought (as well as for others abstract domain as ideas, desires, similarity, etc., see Pinker 2007). The fact that 9 months old babies (Lourenco & Longo, 2010; Srinivasan & Carey, 2010) and non-human animals (Merrit et al., 2010; Merck & Church, 1983; Tudusciuc & Nieder, 2007; Walsh, 2003) show similar magnitude overlaps, should cause us to lean towards this innatist view. Nevertheless, if the presence of functional overlap among representations of space and time correctly predicts cross-domain interference, and that spatial and temporal language should overlap, it does not make any directional prediction (like ATOM). How to explain the space-time asymmetry found across many cultures, in adults and children? (Casasanto & Boroditsky, 2008; Casasanto 2008; and this thesis).

Some possible answers, together with the classic debate between nature and nurture, applied to the relationship between space and time in the human mind, will be further discussed in the last part of this thesis. What is important at this moment is to determine that more studies are needed to clarify if the space-time asymmetry detected in adults and children is present also in infants. The presence of the asymmetry could be explained by a rapidly-learned metaphorical mapping, through sensory-motor experience, or through an innatist point of view: a dilemma that seems hard to resolve. On the other hand, a symmetrical space-time relationship would be consistent with ATOM, matching what Walsh has called "one-bit baby":

"One might consider that an infant begins with a 'one bit' undifferentiated magnitude system, with which the infant responds motorically to changes in size, speed, distance and duration of external events, only learning to differentiate through interaction. As the child learns, it will do so according to the statistics of the environment, an environment in which the space, time, speed, size and quantity of events and objects are often highly correlated." (Walsh, 2003, p. 486)

Such a developmental account, in which the space-time link is viewed as beginning in babies minds as ATOMic and gradually becoming metaphoric, may present a way to put together two theories which we have considered here to be in opposition.

## 7.2 ATOM vs METAPHOR

The prior section outlined why an asymmetrical relationship between representations of space and time is a problem for ATOM and other theories not positing a metaphorical mechanism for the spatial foundation of temporal thought (Srinivasan & Carey, 2010; Bueti & Walsh, 2009; Pinker, 1997; 2007). Such theories do not predict any directionality for the space-time relation, and if an asymmetry is constantly found, it must be addressed. One of the most common arguments is that time and space are actually supported by a more abstract magnitude representation that is used for both dimensions (a restricted version of ATOM, see for example Srinivasan & Carey, 2010), and that spatial representation elicits this more abstract structure, more strongly than temporal representation. This argument has been efficaciously addressed by Lera Borodistky way back in the days (Boroditsky, 2000). If spatial representation recruits the 'general structure' more strongly than the temporal thought, then in a priming paradigm, space should prime time better than time should prime itself. This is predicted because spatial primes would prime the generic, underlying schema more effectively than temporal primes. As Boroditsky has shown, this is not the case. Time has always shown to prime temporal stimuli at least as effectively as space (See Boroditsky, 2000, exp. 2 & 3). Moreover, if the spatial representation is more strongly associated with a general magnitude system than temporal representation, one should expect, in general, that space estimation is more accurate than time estimation, especially in case of interference. We know that across different psychophysical experiments (Casasanto & Boroditsky, 2008) this is not the case.

As we have already seen, Bueti & Walsh offered two possible explanations for asymmetrical patterns between prothetic conceptual domains:

1) Magnitudes can be hierarchically organized from continuous to discrete scales (Hurewitz et al. 2006), therefore the continuous dimensions (e.g. size, duration) have phylogenetic and ontogenetic primacy compared to the discrete dimensions (e.g. numbers). So that discretely conceptualized dimensions are built on the structures used by continuous dimensions (Bueti and Walsh. 2009).

2) These asymmetrical patterns are task-related effects that don't reflect the organization of these representations at the conceptual and neurological level.

As we pointed out above, the hierarchical model proposed by Hurewitz et al. (2006) and put forward by Bueti & Walsh cannot account for cases in which number influences duration judgment (Dormal et al. 2006; Olivieri et al. 2008), or that duration usually does not interfere with numerosity judgments (Dormal et al. 2006). It also fails to explain space-time asymmetry (Casasanto & Boroditsky, 2008; Casasanto & al. 2010), in which the relationship between two continuous domains is asymmetrical.
The concern about task-related effects is more appropriate, although too vaguely formulated (see Bueti & Walsh, 2009) to be addressed here. For this reason, we decided to take into consideration all empirical evidence and theoretical reasons that support ATOM, as well as older (Pinker, 1997; 2007) and newer (Sirinivasan & Carey, 2010) skeptical views on mental metaphors in spatio-temporal representations. Thus, we attempt to provide a structured argument for an alternative explanation of these constantly-observed asymmetries between space and time. We start asking the question: "How would an ATOM theorist re-interpret all the evidence provided so far in order to hold onto the idea of ATOM?"

## 7.3 Asymmetry and perceptual salience

The general argument that we want to propose (on behalf of ATOMists) is the following:

***The asymmetry between space and time it is not in our mind, in our conceptual system or in the way we think about temporal and spatial magnitudes. Rather, the***

***asymmetry is in the stimuli that we use in our experiments and, more generally, in the way we perceive spatial and temporal features of what we call the outside world.***

Although we can perceive spatial variation through different senses (i.e. sight, touch), we cannot perceive temporal variation. As Robert Ornstein suggested in 1969: "*We can never perceive time through the senses. [...] If time were a sensory process like vision...we would have an 'organ' of time experience such as the eye*" (pg. 34). The same verb (*perceive*) is maybe inadequate for the experience of time (see also 4.1.2).
Experience of spatial variations, like displacement or enlargement, always produces a variation in our sensorial organ, in the retina for example. We can say that physical spatial variations are directly perceived through perturbation of the sensorial system. On the other hand, temporal variation alone does not produce any physical variation in our sensorial organs. In principle, the world and our interaction with it, is continuously changing in time, but the flow of time does not perturbate directly our sensorial system.

This situation, that for the sake of simplicity we'll refer to as "perceptual salience", create, *per sé*, a perceptual asymmetry between the experience of space and time even before considering space-time conceptualization or representation. Let's think for a moment to the growing line experiment where one dimension interferes with the other on uni-dimensional judgments. In the case of the duration estimation, subject experience a "spatial percept", the length variation of the line, which can interfere with the duration judgment. But, in the case of length estimation, there is nothing like a "temporal percept" that can interfere with spatial estimation.
The different perceptual salience of the temporal and spatial stimuli can create a perceptual asymmetry that can influence contingent perceptual estimation and lead to asymmetric behavioral outcome, even if the two magnitudes are symmetrically related at the conceptual level.

Differences in discriminability and perceptual salience have been shown to modulate the strength or direction of cross-dimensional interference and priming effects across numerous studies (van Wassenhove et al. 2008; and see Santiago, Román, & Ouellet, in press, for review). In general, the dimension that is more discriminable or salient interferes with the dimension that is less discriminable or less salient. Can task-related differences in the relative salience of stimulus dimensions account for the observed space-time asymmetries?

This possibility is corroborated by the asymmetrical pattern found between numerosity and duration judgment (Dormal et al., 2006), where the numerosity of arrays of dots (with higher perceptual salience) influenced duration estimation more than the other way around. And difference in perceptual salience could be responsible fore most of the asymmetries found in many others interference studies where temporal task are impaired by non-temporal tasks more than vice versa (see Brown 1995 for a review) ,[96] showing how "*time tasks are easily disrupted but are not themselves good disrupters*" (Walsh, 2003, p. 484). For example Thomas & Cantor (1978, quoted in Fraisse, 1984) asked to some subjects to perform in a test were they had to estimate the duration of an array of letters or detect some target letters in the same array. In the "pure condition" they have either to estimate the duration or to detect the letters. In the "mixed condition" the subjects had to perform both tasks contemporary, in some cases the duration estimation task was emphasized by the experimenter as the most important one, in other cases it was the detection task to be emphasized. Decrement in duration accuracy were observed in going from pure to mixed conditions, but not in the detection task. The authors explained that:

> "This asymmetry can be explained by the fact that the two types of stimulation are treated simultaneously but that attention is spontaneously directed to information provided by the stimulus and not to its duration. There are limits in the ability to process information" (cit. in Fraisse, 1984, pag. 16)

As suggested by Paul Fraisse (1967), "l'esperience du temps dépend de tous le facteur du champ perceptif", and the spatial length is definitely part of the perceptive field.

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[96] Unfortunately, just a few studies in the time perception literature investigated pattern of bidirectional interference between temporal and non-temporal tasks. Usually the focus is centered primarily on temporal judgments, and the non-temporal task is viewed simply as a means of distracting subjects from time. Moreover, sometimes the distracting task does not involve magnitude processing, so that it's inadequate to investigate cross-domain interference patterns between time and others magnitude processing.

In this view, the asymmetry is due to the contingent sensorial input, not to the representations, that can be symmetrically related to the representations of other magnitudes, in a common magnitude system. The magnitude system is perturbed by the sensorial system from which receives the information about the magnitude variation of different dimension (like distance, luminance, loudness). These sensorial information can indirectly influence temporal representation, that is part of the magnitude system. But a variation of physical time cannot directly or indirectly influence others magnitude processing, because it doesn't create any variation on the sensorial organs, and consequently, any perturbation that can indirectly interfere with others magnitudes' computation. The symmetric interaction detected between domains with a comparable perceptual salience like size and numerosity (Pinel et al. 2004; Kauffman et al. 2005), luminance and numerosity (Koen-Khadosh et al., 2008), and size and luminance (Pinel et al. 2004) support this hypothesis.[97]

At that point, one could notice that, what here is called "perceptual salience" is one of the reasons, explained by Lakoff & Johnson, why we use a spatial mapping to think and understand temporal relations. Time, as others abstract domains lacks of perceptual foundations and more perceptual-based domain, like space, are recruited in order to provide a stable and ordinate structure. Perceptual salience is one of the main reason why space is the source and time is the target domain, and not vice versa. The Metaphor Theory (in all its different versions and revisits) is a theory of mind and thought, more than a theory of perception. The difference in salience between space and time certainly takes an important role in building up the metaphorical mapping and determining the direction of the conceptual (Lakoff & Johnson, 1999) or mental (Casasanto, 2008) metaphors. But, the metaphorical structure is then established at the conceptual level, so that we use space to think about time even when we are not perceiving any contingent spatial variation, such as when we close our eyes and, lying on the couch, we start thinking about the past or the future. To make clear this point, if the asymmetry is established at the conceptual level, we should be able to detect it even

[97] Moreover, what we have called perceptual salience is associated to the level of automaticity, which has been proposed as a possible explanation for the number-time asymmetry (Dormal et. Al, 2006). It is possible, in fact, that spatial and numeric representations are automatic but not temporal representation. In other words temporal representation need explicit attentional focus to be brought to awarness, which are not needed for spatial and numerical representations.

when the perceptual salience of the two domains (space and time) is equated. For example, imagining spatial and temporal magnitudes without any interfering perceptual variation. Otherwise, if the relation between temporal and spatial magnitudes become symmetrical when they are both internally generated (i.e. imagined), than we can suggest that the space time asymmetry is a task-related artifact, due to different perceptual salience, and that representations of pace and time are symmetrically related in our mind, as predicted by ATOM.

We think this is the most compelling criticism that can be moved to a 'metaphorical' interpretation of the data, so far presented, on the space-time asymmetry. Therefore we are going to present an empirical study which address the problem of the perceptual salience. This study tries to falsify a 'metaphorical' interpretation of the space-time asymmetry nullifying the difference in perceptual salience between spatial and temporal domain, and see if the asymmetry is still there.

# 8. Implicit space influence time estimation, but not vice-versa

## 8.1 Introduction

In the present study, we eliminated differences in perceptual salience by eliminating perceptible variation in the critical dimension (space or time), altogether. We tested whether the implicit spatial information encoded in object nouns can influence estimates of time (in Experiment 1), and whether the temporal information encoded in event nouns can influence estimates of spatial length (in Experiment 2). Participants saw words presented one at a time and reproduced either the duration for which they remained on the screen or their spatial length, using mouse clicks as in Casasanto & Boroditsky (2008). In the duration estimation task (Experiment 1), the target words named objects of various spatial lengths (e.g., *pencil*, *clothesline*, *footpath*). All target words had the same number of letters in Dutch, and therefore the same physical length on the screen. In the spatial length estimation task (Experiment 2) the target words named events of various durations (e.g., *blink*, *party*, *season*). Again, all target words had the same number of letters, but they were presented with a varying number of spaces between letters (1-9 spaces), stretching them out to different spatial lengths on the screen.

Word meanings were irrelevant to the length and duration estimations. We expected, however, that participants would read the words while viewing them, and activate their meanings (voluntarily or involuntarily). Presumably, the meaning of an object noun typically includes a representation of the object's spatial form, and the meaning of an event noun a representation of the event's duration. If internally-generated spatial and temporal representations cued by words are sufficient to modulate estimates of experienced duration and spatial length, then we should observe cross-dimensional interference. Following metaphor theory, we predicted that the cross-dimensional interference should be asymmetric, even in the absence of cross-dimensional differences in perceptual salience: spatial representations cued by object nouns should modulate estimates of their duration more than temporal representations cued by event nouns modulate estimates of their spatial extent on the screen.

## 8.2 Experiment 1: Does implicit spatial length modulate time estimates?

Experiment 1 tested whether the spatial length of a word's referent can modulate estimates of how much time the word remained on the screen.

### 8.2.1 Methods

Participants: Native Dutch speakers (N=39) performed Experiment 1 in exchange for payment.

Materials: Dutch nouns naming 9 concrete objects (Targets) and 9 abstract entities (Fillers) were presented on a computer monitor (resolution = 1024 x 768 pixels) for varying durations. The concrete nouns referred to objects whose characteristic spatial lengths ranged from short (normally measured in centimetres) to long (normally measured in kilometres). English equivalents of these nouns are listed here in order of increasing length: *cigarette*, *pencil*, *ruler*, *meter stick*, *bench, clothesline*, *footpath*, *lane*, *highway.* In Dutch, all 9 target nouns had 7 letters, and were presented on the screen in a fixed-width font (62-point Courrier New). Therefore, the targets did not differ in their physical spatial lengths on the screen; rather, they differed in their implicit lengths (i.e., the typical spatial lengths of their referents).

The filler nouns referred to abstract entities that have no physical spatial length: *guess*, *idea*, *pride*, *opinion*, *envy*, *thought*, *philosophy*, *suspicion, dignity*. However, they varied in their number of letters in Dutch (from 3-11 letters) and therefore in their physical length on the screen (nine different lengths, varying from 50-450 pixels as measured from the left edge of the first letter to the right edge of the last letter). By contrast with the targets, the fillers did not differ in the implicit lengths of their referents; rather, they differed in their physical lengths on the screen.

Each target and filler word was presented 9 times throughout the experiment, for 9 different durations. Durations ranged from 1000 to 5000 ms in 500 ms increments. Fully crossing these 9 durations with the target words (which had 9 different implicit spatial lengths) produced 81 target trials. Likewise, fully crossing the 9 durations with the 9 filler words (each one with a different physical lengths on the screen) produced 81 filler trials. The 162 different trials were presented in random order, with fillers and targets intermixed. Words were presented in white letters on a black background in the center of the screen. Participants were tested individually and testing lasted about 30 min.

*Procedure*: Participants viewed the 162 words, one word at a time, from a viewing distance of approximately 50 cm. Immediately after each word disappeared an "hourglass" icon appeared in the upper left corner of the monitor indicating that the subject should reproduce the amount of time the word remained on the screen. To estimate duration, subjects clicked the mouse once on the center of the hourglass, waited the appropriate amount of time, and clicked again in the same spot, thus indicating the beginning and end of the temporal interval. All responses were self-paced.

After the experiment there was a two-part debriefing. In the first part, the experimenter asked the participant "What do you think this experiment is about?" and "What do you think we were looking for?" to determine whether the participant was aware of any relationship between the implicit lengths of the target words and their durations. In the second part, participants saw each target word again, in random order, and verbally estimated the typical spatial length of the target words' referents (using an appropriate unit of measurement). These subjective length estimates were used in later analyses as predictors of subjective duration.

### 8.2.2. Results and Discussion

Four participants were removed from the analyses below: one for giving nonsensical answers in the debriefing, one for excessively poor time estimation performance according to the criterion used by Casasanto & Boroditsky (2008)[98], and

[98] Participants were excluded if the slope of their within-domain duration or length estimates was less than 0.5 (see Casasanto & Boroditsky, 2008). This criterion, which resulted in the exclusion of only one participant overall, is unbiased with respect to the predicted cross-dimensional interference because length and duration are orthogonal in the designs of both experiments.

two for guessing the that there was a connection between the meanings of the target words and time estimation.

For the remaining 35 participants, we first analyzed participants' duration estimates as a function of the actual duration of the stimuli. Overall, duration estimates for target words were highly accurate (mean effect of actual duration on estimated duration: $y=0.83x + 154.11$, $r^2=.99$, df=7, $p<.001$; fig 1a).

We then tested for effects of implicit length on duration estimation. Target words were rank-ordered according to the typical lengths of their referents (this *a priori* ranking was confirmed by participants' post-test length estimates). Non-parametric correlation showed that implicit spatial length affected estimates of duration ($y=3.77x + 2605.70$, $r_{s(\text{Spearman's rho})}=0.75$, df=7, $p<.05$ fig.1b).

Finally, we conducted a parametric analysis of the effect of implicit length on duration estimation. Participants' post-test ratings of the typical spatial length of each target word's referent were used as a predictor of their duration estimates. Ratings for each target item were averaged, and the average length estimates in meters were transformed by a base 10 logarithm. This analysis corroborated the non-parametric analysis, showing a highly significant effect of implicit spatial length on duration estimation ($y=5.60x + 2619.20$, $r^2=.57$, df = 7, $p< .001$).

Participants incorporated irrelevant spatial information into their temporal estimates. For stimuli of the same average duration, words with (spatially) shorter referents were judged to remain on the screen for a shorter time, and words with longer referents for a longer time. This was true even though the task did not require participants to process the words' meanings.

This result shows that perceptible spatial input is not necessary to modulate time estimates; rather, internally- generated spatial representations cued by words are sufficient. This outcome, *per se*, is equally consistent with metaphor theory and with ATOM. To distinguish between the theories, it is necessary to conduct a complementary experiment to determine whether implicit duration can affect estimates of spatial length, and whether cross-dimensional interference effects are as symmetric, as expected on ATOM (Effect of Space on Time ≈ Effect of Time on Space) or asymmetric, as predicted by metaphor theory (Effect of Space on Time > Effect of Time on Space).

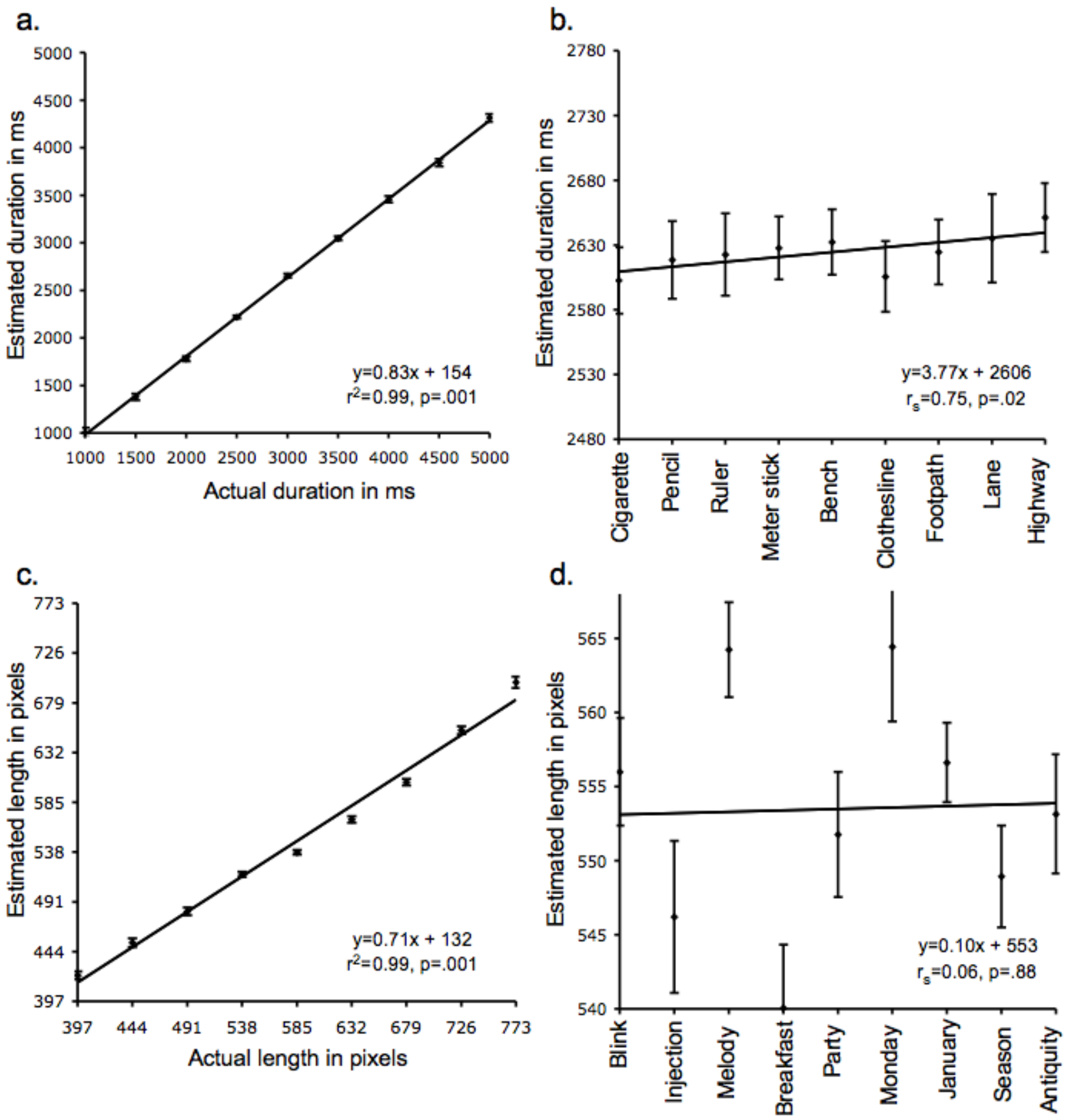


Figure 14. Results of Experiment 1 (top) and Experiment 2 (bottom). 1a. Within-domain effect of actual word duration on estimated duration. 1b. Cross-domain effect of words' implicit spatial length on estimated duration. 1c. Within-domain effect of actual word length on estimated spatial length. 1d. Cross-domain effect of words' implicit duration on estimated spatial length. The axes of the top and bottom plots (a-c, b-d) are proportional with respect to the total range of target values. Error bars show s.e.m.

## 8.3 Experiment 2: Does implicit duration modulate estimates of spatial length?

Experiment 2 tested whether the duration of a word's referent can modulate estimates of the word's spatial length as presented on the screen.

### 8.3.1 Methods

Participants: Native Dutch speakers (N=35) performed Experiment 2 in exchange for payment.

Materials: Dutch nouns naming 9 events (Targets) and nine concrete objects (Fillers) were presented on a computer monitor (resolution = 1024 x 768 pixels). The target nouns referred to events whose characteristic durations ranged from short (normally measured in seconds) to long (normally measured in years). English equivalents of these nouns are listed here in order of increasing duration: *blink*, *injection*, *melody*, *breakfast*, *party*, *Monday*, *January*, *Season*, *Antiquity.* All targets were presented for 3000ms. Therefore, the targets did not differ in the physical durations for which they remained on the screen; rather, they differed in their implicit durations (i.e., the typical durations of their referents).

The filler nouns referred to concrete objects that have no inherent duration: *doormat*, *ballast*, *portrait*, *detritus*, *crystal*, *device*, *little case*, *sawdust, handle*. Each filler noun appeared for 9 different durations from 1000-5000ms, increasing in 500ms increments. By contrast with the targets, the fillers did not differ in the implicit durations of their referents; rather, they differed in the physical durations for which they remained on the screen.

In Dutch, all target and filler nouns had seven letters, and were presented on the screen in a fixed-width font (62-point Courrier New). Each word was presented 9 times throughout the experiment, with a varying number of spaces in between the letters (1-9), to stretch the words out to 9 different spatial lengths on the screen. Due to the font selected, word lengths ranged from 397 to 773 pixels, in 47 pixels increments. Presenting each word at each of these 9 spatial lengths produced 81 filler trials and 81 target trials. For the fillers, spatial length was fully crossed with the physical duration for which they were presented. For the targets, spatial length was fully crossed with the implicit duration of their referents. The 162 different trials were presented in random order, with fillers and targets intermixed. Words were presented in white letters on a black background in the center of the screen. Participants were tested individually and testing lasted about 30 min.

*Procedure*: Participants viewed the 162 words, one word at a time, from a viewing distance of approximately 50 cm. Immediately after each word disappeared an "X" appeared in the upper left corner of the monitor indicating that the subject should reproduce the spatial length that the word had occupied on the screen. To estimate length, subjects clicked the mouse once on the center of the X, moved the mouse to the right the appropriate distance, and clicked again, thus indicating the beginning and end of a spatial interval. All responses were self-paced.

After the experiment there was a two-part debriefing, as in Experiment 1. The first part was to determine whether the participant was aware of any relationship between the implicit durations of the target words and their spatial lengths. In the second part, participants saw each target word again, in random order, and verbally estimated the typical duration of the target words' referents (using an appropriate unit of measurement). These subjective duration estimates were used in later analyses as predictors of subjective spatial length.

### 8.3.2 Results and Discussion

One participant was removed from the analyses below for guessing that there was a connection between the meanings of the target words and spatial length estimation.

For the remaining 34 participants, we first analyzed participants' spatial length estimates as a function of the actual spatial length of the stimuli. Overall, length estimates for target words were highly accurate (mean effect of actual length on estimated length: $y=0.71x + 132.44$, $r^2=.99$, $df=7$, $p=.001$; fig 1c).

We then tested for effects of implicit duration on spatial length estimation. Target words were rank-ordered according to the typical durations of their referents (this *a priori* ranking was confirmed by participants' post-test duration estimates). Non-parametric correlation showed that implicit duration did not affect estimates of spatial length ($y=0.10x + 553.00$, $r_{s(\text{Spearman's rho})}=0.06$, df = 7, *ns*; fig.1d).

Next, we conducted a parametric analysis using participants' post-test ratings of the typical duration of each target word's referent were used as a predictor of their length estimates. Ratings for each target item were averaged, and the average duration estimates in minutes were transformed by a base 10 logarithm. Again, there was no effect of implicit duration on spatial length estimation ($y= 0.04x + 553.39$, $r^2=.0003$, df=7, *ns*).

Finally, we compared the strength of the cross-dimensional interference effects across Experiments 1 and 2. The difference of correlations showed the predicted cross-dimensional asymmetry ($r_{\text{effect of spatial length on duration}}-r_{\text{effect of duration on spatial length}}=0.74$, z=1.66, p=0.05, one-tailed; see fig. 1b, 1d). This difference cannot be attributed to differences in within-domain performance ($r_{\text{effect of actual duration on estimated duration}}-r_{\text{effect of actual spatial length on estimated spatial length}}=0.00$, z=0.00, *ns*; see fig. 1a, 1c).

## 8.4 General Discussion

This study tested whether implicit spatial information encoded in concrete object nouns can influence estimates of time (in Experiment 1), and whether implicit temporal information encoded in event nouns can influence estimates of spatial length (in Experiment 2). When participants reproduced the duration for which an object noun remained on the screen, their estimates were influenced by the implicit length of the word's referent. Words that named shorter objects (e.g., *cigarette*, *pencil*) were judged to last a shorter time, and words that named longer objects (e.g., *bench*, *highway*) to last a longer time. By contrast, when participants reproduced the spatial length of an event noun, the duration of the word's referent did not influence judgments of spatial length.

This asymmetric pattern of cross-dimensional interference was predicted based on patterns in language: people talk about time in terms of space more than they talk about space in terms of time (Lakoff & Johnson, 1999). These data show that people incorporate spatial information into their temporal judgments even when they're not using any metaphorical language, and support the hypothesis that mental representations of time are asymmetrically dependent on representations of space: people use spatial length to think about duration, more than vice versa.

This space-time asymmetry cannot be attributed to differences in how well participants were able to reproduce the actual durations and lengths of the stimuli, *per se*. The actual duration of object nouns accounted for 99% of the variance in duration judgments, and the actual spatial length of event nouns accounted for 99% of the variance in length judgments. Thus, differences in cross-dimensional interference were not due to differences in within-domain performance.

Furthermore, the space-time asymmetry cannot be attributed to differences in the perceptual salience of the interfering dimensions (i.e., space in Expt. 1, time in Expt. 2). In previous experiments, space could have influenced time asymmetrically because space is inherently more perceptually salient than time (which some scholars have argued can never be perceived directly (Ornstein, 1969)). But here there was no perceptible variation in the spatial component of duration-reproduction stimuli, and no perceptible variation in the temporal component of length-reproduction stimuli. Internally-generated representations of spatial length, cued by words, were sufficient to modulate estimates of the words' physical duration. This was true even though the words' meanings were task-irrelevant.

Before discussing theoretical implications of these data further, it is important to consider whether the observed pattern could be due to unintended features of the stimulus words. For example, is it possible that duration estimates in Experiment 1 were influenced by implicit *speed* encoded in the concrete nouns, rather than implicit length? The three longest objects (*footpath*, *lane*, and *highway*) are all spatial paths. The speed of motion associated with these paths increases with their lengths (i.e., *footpath-walking*, *lane-slow driving*, *highway-fast driving*). The conflation of length and speed in these items was a consequence of restrictions on the stimuli: items had to increase in ordinal length unambiguously, and had to have 7 letters in Dutch.

If the effect of object length on duration estimates had been driven by these three items, this would be problematic. However, even a causal inspection of fig. 1b shows this was not the case. For the majority of the items there were no clear speed associations, and yet the effect of implicit length was found. For the first 5 items (*cigarette*, *pencil*, *ruler*, *meter stick*, *bench*), ordinal increases in implicit length corresponded to a monotonic increase in estimated duration. The predicted effect of length on duration was significant in these 5 items, alone (y=6.84x + 2600, $r_{s(\text{Spearman's}}$

$_{\text{rho)}}=1.00$, $p=.001$). Thus, implicit speed was not responsible for the effect of implicit spatial length we report here (see Casasanto & Boroditsky, 2008, Expt. 6 for further evidence that spatial length affects duration estimates independent of speed). Whether the implicit speed of a word's referent can influence estimates of the word's duration remains a question for future research.

On another skeptical possibility, could implicit *duration* encoded in object nouns have produced the observed effect on duration estimation? Looking at the longest and shortest items alone, this seems plausible. *Cigarette* could be associated with the time it takes to smoke a cigarette (a short time), and *highway* with the amount of time one typically drives on a highway (a longer time). Yet, looking at the full range of stimuli, this alternative explanation seems implausible. What durations are prepotently associated with *clothesline*, *pencil*, *ruler*, *bench*, or *meter stick*? Ordinal increases in spatial length predicted ordinal increases in duration estimates for 7 out of the 8 ordinal pairs of stimuli (i.e., *cigarette* < *pencil*; *pencil* < *ruler*; *ruler* < *meter stick*; etc.) Pairwise differences in the typical spatial lengths of the words' referents are self-evident (and were confirmed by participants' post-test ratings), but for most of these word pairs, it seems unlikely that there are corresponding pairwise differences in durations associated with the words' referents.

Finally, although the space-time asymmetry cannot be due to differences in the *perceptual salience* of the interfering dimensions, could they be due to differences in *conceptual salience*? Could the spatial component of the object words' meanings be more salient than the temporal component of the event words' meanings? We cannot rule out this possibility definitively, but this seems unlikely to be the case. It is difficult to evaluate how salient spatial length is in the meaning of *bench* or *cigarette*, and to compare this with the salience of temporal duration in the meaning of *melody* or *party.* But a few of the stimuli are very strongly associated with a unit of space (*ruler*, *meter stick*) or a period of time (*Monday*, *January*, *season*, *Antiquity*). For these items, it is reasonable to assume that a spatial or temporal representation is the most salient aspect of the word's meaning. This was the case for only two of the object words (22% of targets) but for four of the event words (44% of targets). Therefore, overall, it seems likely that any asymmetry in conceptual salience favored the temporal meanings of the event words, thus working against the hypothesized space-time asymmetry.

It is known that internally generated spatial magnitude can influence duration estimation as well as perceived ones. For example Zach and Brugger (2008) asked their participants to imagine a standard Swiss railway clock either at a distance of 30 cm or 6 m, and provide estimates of elapsed durations of 15 and 30 seconds. Duration estimates were shorter for the clockface imagined farther away (thus with a smaller size) than for the one imagined immediately close (and with a bigger size). However, in our study the cross-domain influence of internally generated spatial and temporal magnitudes has been investigated bi-directionally, for the first time.

Our results suggest that the asymmetric dependence of time on space in psychophysical judgments is not an artifact of perceptual or conceptual asymmetries built into the stimuli. Rather, this performance asymmetry reflects a fundamental difference in the way people mentally represent space and time. But this asymmetric relationship between space and time in the mind may, indeed, result from an asymmetry in how perceptible space and time are more broadly -- not in any particular experimental stimuli, but rather in the observable world, in general. Space and time are correlated in our everyday experiences (e.g., as objects travel farther more time passes), and tracking these correlations may be useful for anticipating changes in the physical environment. Correlation is a symmetrical relationship, but people may rely more heavily on the more perceptually available dimension (space), using it heuristically as an index of changes in the less perceptible dimension (time).

It appears that time and space are, in Garner's (1976) terminology, *asymmetrically separable* dimensions: it is possible to ignore irrelevant variation in time while judging space but not possible (or more difficult) to ignore irrelevant variation in space when judging time. At present, there is nothing in Walsh's (2003) ATOM proposal that can predict or explain the asymmetric separability of space and time. Yet, this cross-dimensional relationship is readily predicted by metaphor theory. Importantly, space and time are predicted to be related *asymmetrically* but not *unidirectionally.* There is evidence that time can influence space in some paradigms (e.g., Miles, Nind, & Macrae, 2010), just as people can sometimes use temporal words to talk about space (e.g., "*I live two minutes from the station*" is a temporal metaphor for spatial distance). Simply showing that time can influence spatial judgments in some cases does not challenge the asymmetry we report here: to address the question of asymmetry, the cross-dimensional influences of time and space must be appropriately compared, controlling for salience and discriminability across dimensions, and for within-dimension performance (see Casasanto & Boroditsky (2008) for discussion).

We propose that Garner-like tests of dimensional separability will be critical for either modifying ATOM or deciding to abandon it in favor of a metaphorical theory of spatial, temporal, and numerical magnitude representation. In order to understand how space, time, and other prothetic dimensions are represented in the brain and mind, it is necessary to go beyond investigating *whether* these dimensions interact and determine *how* they interact.

# 9. Conclusion

We provided evidences that the space-time asymmetry detected across many psychophysical and psycholinguistics experiments with adults and children it is not a task-related effect due to the difference in perceptual salience between the spatial and temporal aspects of the stimuli. Implicit spatial information encoded in concrete object nouns influence estimates of time (Experiment 1), but, implicit temporal information encoded in event nouns do not influence estimates of spatial length (Experiment 2). Even when the perceptual salience is re-equilibrated, avoiding any physical/perceptual variation of the interfering dimension during magnitude judgments, the asymmetry is still there and *space* (distance, length) influences *time* (duration) more than the other way around. This empirical study provide direct evidence that the space-time asymmetry it is not due to contingent perceptual salience of the stimuli used in cross-dimensional interference studies, but is linked to the modality in which space and time are conceptually represented in mind (independently of the simultaneous temporal or spatial variation of physical objects). Moreover, indirect evidence which lead to discard such a task-related effect as a possible explanation of the asymmetry come from the experimentation with non human animals. Merritt and colleagues (2010) has shown how human and rhesus monkeys produce different results in psychophysical space-time bisection test (See 7.1). In the case in point, humans showed a classic space-time asymmetry: irrelevant spatial information influenced duration judgments more than the other way around. On the other hand, in the same bisection test, rhesus monkeys showed a symmetrical pattern: irrelevant spatial information significantly influenced temporal judgment as well as irrelevant temporal information influenced spatial judgment. These results, beyond providing interesting data suggesting the possibility that the space-time asymmetry is specie-specific (or human-specific in this case), are also important for the theoretical point discussed here. In fact, results show that in rhesus monkeys the interaction between space and time is symmetrical, as predicted by ATOM, despite the difference in perceptual salience between spatial and temporal aspect of the stimuli. Being the stimuli and the procedure of the experiment the same between human and non-human participants, the differences that has been found can hardly been imputed to task-related effects. In fact, the perceptual conditions (difference in perceptual salience between time and space), can be generalized across species because both in humans and monkeys, spatial variations in the stimuli cause (sensory) organ perturbation whereas temporal variation does not.[99] The symmetrical effect of space-on-time and time-on-space found in rhesus monkeys behavior support the hypothesis that the human space-time asymmetry it is not due to difference in perceptual salience between spatial and temporal aspects of the stimuli.

A large amount of data, coming from linguistic, psycholinguistic, and psychophysical studies suggest that temporal reasoning and conceptualization depend on spatial reasoning and concepts more than the other way around, as predicted by Metaphor theory (Lakoff & Johnson, 1999; Boroditsky, 2000; Casasanto & Boroditsky, 2008). This is indeed true also for the special case of temporal (and spatial) magnitude representation. Even if some psychological and neurological theories has suggested that 'space' and 'time' representations are not based on two independent cognitive modules in our mind, but share instead cognitive and neurological structures resulting therefore strictly coupled in human thinking (Walsh, 2003; Mauk & Buonomano, 2004; Pinker, 2007; Carey & Srinivasan, 2010), none of them necessarily predict that this relation should be asymmetric. In this chapter we have extensively considered one of these theories, called ATOM, recently proposed by Vincent Walsh (2003). According to ATOM, representation of spatial and temporal magnitudes, as well as representations of magnitude in general, all depend on the same magnitude metric system, whose primary neural location is in the right IPS. A magnitude system that we share with monkeys and probably with other animal species, and which, therefore, has phylogenetic origins. Implicit in ATOM is the assumption that space and time are symmetrically interrelated in brain and mind. This assumption, though, has been falsified, in its general terms, by many empirical evidences (Chapter 7) including the experiment presented above (chapter 8).

We tried to reconcile the data supporting the space-time asymmetry, with the ATOMic view (see 7.1), especially on the light of studies on very young children that

[99] Someone might not completely agree with this consideration, suggesting that an organ of time, maybe an 'internal' organ like a biological or cerebral clock, is instead perturbed during variations of physical time. In such a case supporters of this theory should face with all the theoretical and practical problems which derives from a conception of temporal experience as a sensory experience (See cap. 3-4-5).

show symmetric generalization of associative patterns across temporal, spatial and numerical magnitudes (Lourenco & Longo, 2010). One possibility in this sense, roughly explored above, is that the relationship between space and time in human mind start symmetric (as predicted by ATOM) and become asymmetric during the ontogenetic development, on the basis of a metaphorical mapping based on sensory-motor experience. Indeed, further studies supporting space-time symmetry in newborns and young children are required, ideally using an interference paradigm rather than a generalization one (see 7.1). The hypothesis of a primary symmetric relationship between magnitude representations of space and time, which become asymmetric later, on experiential basis is compatible with Metaphor Theory.

However, if several findings from different fields supports Metaphor Theory suggesting that we conceive and reason about time on the basis of a spatial metaphor, quite a little it is known about the mechanisms which underlie this process of mapping, the temporal span and the conditions under which it takes place. How do spatial and temporal reasoning become asymmetrically linked? In which way time is progressively 'spatialized' through experience? Is this process of spatialization equal for every one or could change according to biological and/or cultural constraints? To what extent?

In chapter 5 we have seen how the classic version of MT explain the formation of metaphorical mapping. We are going to represent it here, with more details, before introducing the next and last part of this thesis, which tries to answer to some of the questions asked above.

Following the classic formulation of the Metaphor Theory (Lakoff & Johnson, 1980; 1999), time and space are linked by a conceptual mapping which goes from the Source Domain, *space*, to the Target Domain, *time*. These domains are supposed to be independent and differentiated at the beginning, becoming metaphorically (therefore asymmetrically) related through everyday sensory-motor experience.

Therefore, a non-spatialized, pre-metaphorical concept of time, which would receive the mapping from the *Source Domain* (spatial extension, spatial movement) is required. According to Lakoff & Johnson, this basic temporal representation (the Target domain) is based on the experiences of events and their comparison. We cannot perceive time directly, but always on the basis of something else, like the events and its relations. As suggested already by Gibson (1975), "event are perceivable, time is not". Therefore, what Lakoff and Johnson called "literal time" is based on a metonymycal cognitive mechanism according to which the directional, irreversible, continuous, segmentable, and measurable character of events is imposed upon time by the experience of repetitive, regular 'time-defining' events (Lakoff & Johnson, 1999). Time-defining events are regular and iterative events that are conventionally used to measure time. This measure, however, it is always a comparison between events, for example we can measure the duration of a concert (event 1) by comparison with a reiterate, regular event like the motion of the hand of a clock (event 2). According to Lakoff & Johnson we define time by metonymy because we let that successive iterations of a type of event stay for intervals of time:

"Cosequentely, the basic literal properties of our concept of time are consequences of properties of events: 1) Time is directional and irreversible because events are directional and irreversible (events cannot unhappen); 2) Time is continuous because we experience events as continuous; 3) Time is segmentable because periodic events have beginnings and ends; 4) Time can be measured because iterations of events can be counted" (Lakof & Johnson, 1999, p. 138)

According to Lakoff & Johnson, we can only define time to be that which is measured by regular iterated events. This metonymical, literal concept of time is the Target domain of the metaphorical mapping from space to time. This mapping, though, starts again as a metonymy. According to Metaphor Theory, in some particular experiences, usually called primary scenes (Grady, 1999; Lakoff & Johnson, 1999) the Target (time-defining events) and the Source domain (movement in space) are conflated together so that one can stand for the other and vice versa. This is the case of everyday motion-situations:

"In literal motion-situations […], metonymy is possible. The reason is simple: a motion situation defines a single complex conceptual schema in which the two domains of time (that is, time defining events) and motion are present together as part of a single whole. Where two things are correlated in such a schema, one can stand metonymically for the other. For example time duration can stand metonymically for distance as in 'San Francisco is half an hour from Berkeley'. Here, half an hour, the time it takes to travel the distance, stands for the distance. The metonymy can go the other way as well; distance can stand metonymically for time, as in 'I slept for fifty miles while she drove'. Here fifty miles is the distance corresponding to the amount of time slept" (p. 152)

In these motion-related primary scenes more space (e.g. distance covered) correspond to more time (e.g. duration elapsed). So that magnitude of one domain increase and decrease symmetrically to the other. These primary scenes in which space and time are conflated together provide the basis for the metaphorical mapping that take place when temporal experience is not associated to movement in space. So that we think about a deadline that is *approaching* even if there is not actual movement, or we conceive duration as distance even if any spatial path has been covered. In other words, the literal correspondence of space and time in these primary scenes is generalized and become a metaphorical correspondence in other temporal experience.

It is important to remark how, once the space-time metaphorical mapping is established, the relationship between spatial and temporal representation become asymmetric even in the case of primary scenes. In fact, in motion-situations where space and time are conflated and metonymically linked, this link is expected to be symmetric since: "one can stand metonymically for the other" (ibid. p. 153). Nevertheless, in experimental settings in which a motion-situation was reproduced both with adults (*Growing line Experiment*; Casasanto & Boroditsky, 2008, and chap. 7) and with children (*Racing Snails experiment*; Casasanto et al. 2010, and chap. 7) the influence of space on time was found to be stronger than vice versa.

To sum up, according to the classic version of MT (Lakoff & Johnson, 1999), a large part of our conceptualization of time is metaphoric, the rest is metonymic. The process of mapping described above, originally based on the experience of primary scenes in which time and space are conflated together, explains the potential universality of such a mapping:

"What all this show is that the Time Orientation, Moving Time, and Moving observer metaphors, which occur widely around the world, are not arbitrary, but are motivated by the most basic of everyday experiences. Such commonality of motion-situations and the correlational structure within motion-situations explain why those metaphors should exist in the form they do and why they should be so commonplace" (Ibid. p. 153) and

"The moving observer metaphor arises spontaneously as part of the cognitive unconscious in conceptual systems around the world, because the motion situations that give rise to that metaphor occur everyday in virtually everyone's experience" (Ibid. p. 153)

In the third part of this work, we are going to investigate the universal and relative aspects of the space-time metaphorical mappings across languages and cultures. We will show how, if the spatialization of time is widespread and potentially universal, the way different people spatialize time in their habitual thought can significantly change according to the culture and the language of a community. In other words we are going to show how the spatial schemas that we use to represent the temporal domain are not exclusively based on the sensory-motor experience. This investigation will lead us to display interesting phenomena of culture relativity and linguistic relativity of thought, which integrate the classic formulation of MT rather than challenging it, demonstrating how also cultural and linguistic features (beside sensory-motor experiences) can significantly influence the construction of the metaphorical mapping and shape the way we think about time. Nevertheless, we will also consider the radical claim according to which members of determined populations, who might not use spatial metaphor to talk about time, do not think about time in terms of space, challenging the sensory-motor basis of the space-time mapping and its presumed universality. Finally, on the light of this considerations about cultural and linguistic relativity we will reconsider the process which underlie the construction of the metaphorical space-time mapping.

# PART 3
# How culture and language shape our representation of time

# Introduction

In the second part of this thesis, we have considered the basic aspect of the experience of duration, investigating low cognitive process, brain areas, and perceptual processes that can underlie basic timing behaviors as duration judgments. Indeed, human experience of time consists in much more than timing an interval of few seconds or to decide which of two images lasts for a longer time on a computer screen. Our experience of (or knowledge about) time is extremely complex, and can be represented in our though, language and gesture in many different ways, most of which are metaphorical. For example, according to our gestures (but also our linguistic expressions), the future is in front of us and past is on the back, a saggittal spatial mapping that is reversed in other cultures like the Aymara (Nunez & Sweester, 2006). Linguistic expressions like "we are approaching the deadline" and "the deadline is approaching us" refer to quite different ways of mentally represent the succession of events in time. The first expression refer to a metaphorical schema that has been called 'ego-moving' (see Chap. 5), for which time is like an extended path and we can go through this path passing one event after the other; The second expression, though, depict a different representation of temporal succession: in what has been called the 'time-moving' (or event-moving) schema, events flow toward us from the future one after the other. We have seen in chapters 5 and 7 how the use of one conceptual schema ,instead of the other, can influence our decisional processes and temporal judgments (Boroditsky, 2000). Moreover, in English, and in other languages, there are frequent metaphorical expressions which associate time with money or other valuable commodity: e.g. "You're *wasting* my time" or "I've *invested a lot* of time in her".

Beyond language and gestures, the representation of time of a community of people can emerge from others cultural variables such as artifacts, rituals, ceremonies, habituals behaviors, etc.

The social psychologists Robert Levine (Levine, 1997, 1999) has studied how the temporal perspective varies between dozens of different cultures around the world. For example, he studied what he has called the 'pace of life' of a community. The peace of life is the relative rapidity (or density) of experiences, meanings, perceptions and activities in the active life of individuals (Levine, 1999). Classic indicators of the peace of life are walking speed, work speed among postal clerks, and accuracy of bank clocks.

Levine and colleagues have measured simple behaviors as the velocity of people walking out of a bar, or the time necessary to buy a stamp at the post office in many different cities of the world. It turned out that Western European countries are the ones with the higher pace of life, with (according to all the classic stereotypes) Switzerland at the top of the list. On the other hand, 'second world' countries occupied mostly the places at the bottom of the list, with the lower pace of life. Interestingly, Levine has found that the pace of life correlate: a) with the degree of 'helping behavior' (e.g. Help a blind person to cross the street; give a change for a quarter; mail a 'lost' letter), for which the cities with the fastest pace of life (e.g. New York) are the least helpful (Levine, 1997); b) with the incidence of coronary diseases: cities with the higher pace of life had also the higher death rates from heart disease (Levine et al., 1989). Indeed, time has a relevant importance in organizing people life in western world. Consider, for example, that according to the Oxford English Dictionary three of the 10 most common English words are temporal, with the word 'Time' at the first place, 'Year' at the third and 'Day' at the fifth place.[100]

However, since a great part of our representation of time is conceived in terms of space, it is the case that different cultures 'spatialize' the flow of time in different ways. In the first chapter we have seen that most of the ancient civilizations had a circular representation of the flow of time, based on the eternal recurrence of seasons and others natural events, and on the circular (apparent) motion of the starry sky. This circular spatialization of time that was well represented in some cultures by human artifacts such as calendars. We can point to the ancient Mayan calendar as an emblematic example, composed by three concentric circles which symbolized synchronized cycles of 13, 20, 360 days, which constantly repeated themselves. Cyclical representations of time were widespread among ancient civilizations, were prevalent in the ancient Greece and they are still used in many contemporaneous cultures. In the modern western world, however, the most common representation of time is not circular but linear, and derives from the Jewish-Christian tradition (See chapter 1). It is the time line that we learn to represent at school, in which the days follow each other from the past to the future, and the time that has been will never come back.

Within linear representations of time, the direction of the time-line can be different for different cultures: if for American or Italian people time flows from left to right, for Israeli and Moroccan it goes in the opposite directions. It is whort remarking that each of these peculiar spatial representations of time it is not only imperceptibly wafting in the history of a community, making it concrete appearance in 'worst-selling' books of cultural studies, but is also part of our everyday experience when, for example, we check the calendar or we read a comic strip on the newspaper.

[100] Source: Zimbardo & Boyd (2008, p. 43)

Can different cultural representation of (spatialized) time influence the way we reason about time in general? Since we have seen compelling evidences for the automatic activation of spatial conceptual structures during temporal cognitive tasks, it is licit to ask if the effect of space on time can assume different forms according to the cultural diversity of temporal representation. Cultural effects which can be based both on beliefs and opinion about the nature of time that have been inculcated in our mind from the childhood, and on our everyday experience of graphic and symbolic representations of time.

In the first part of this session we will consider a particular case of cultural relativity of time representation: temporal direction. In particular, we will refer on the left-to-right or right-to-left direction of the imaginary time line as it is represented in different cultures.

Do people that usually represent the flow of time from left to right (e.g. Americans, Dutch, Italians) think about time in a different way compared to people that usually represent time as flowing from right to left (e.g. Moroccan)? More specifically, do these people automatically activate a different spatial schema in processing temporal concepts?

These questions are of particular interests because investigate the psychological 'reality' of a conceptual metaphor (i.e. Past is Left, and Future is Right; or the reverse) which is common in many symbolic and graphic representation of time (Calendars, charts, temporal sequences) but it is absent in all languages (Santiago et al. 2007).[101] Indeed, if front/back metaphors for time, along a sagittal axis, (e.g. 'Back in the 70's'; 'A bright future is in front of us') are present in many languages (Clark, 1973; Haspelmath, 1997; Núñez & Sweetser, 2006), the left/right metaphorical mapping (e.g. 'The rightward month'; 'Left to the past') has never been described in any idiom (Clark, 1973). Moreover, in our contribution we will try to understand which are the experiential basis of the left-to-right (and right-to-left) space time mapping, its relations with the orthography, and its flexibility and adaptation to the modulation of the environment.

In the second part of this chapter we are going to focus on a particular and significant aspect of human cultural diversity: different natural languages. Indeed, the spatial metaphors used to talk about time, often varies across languages, independently of other evident cultural aspects such as cosmological and religious view, or graphic representations.

We have already seen how different languages use different spatial metaphors to talk about time. We have talked about the Aymara, for which the 'last year' is the 'front

[101] With the exception of many sign languages (Santiago et al. 2007)

year' (*nayra mara*), and 'a future day' is a 'behind day' (*qhipüru*).[102] A spatialization of time that we can find encoded also in Chinese, for which the expression which refers to "the day before yesterday" can be literally translated as "The front day" (Lai & Boroditsky, in press). But this is just one example in the long list of linguistic differences in temporal (metaphorical) expressions. We have reviewed many studies which provide evidences for the psychological effectiveness of the metaphorical mappings encoded in natural languages (See chap. 5 and 7), and we have seen how different metaphorical mapping in language sometimes correlate with different non-linguistic expressions or behaviors such as gestures (as in the case of the Aymara front/back reversed mapping). Until now, we have mostly considered a theoretical point of view according to which these metaphorical mappings are based on perceptual and sensorimotor experience of the world, and the metaphorical expression that we find across all the natural languages are merely the 'reflex' of pre-existent, experience-based conceptual structures. As Lakoff & Johnson have pointed out many times, metaphors are primarily matters of thought and action, and only derivatively of language (Lakoff & Johnson, 1980; 1999).

This position has some important implications. First of all, if the metaphorical space-time mapping is derived by the sensorimotor and perceptual experience of the world, to the extent that people live in comparable environment (with the same laws of physics) and have comparable bodies, their space-time mapping should be more or less the same. In principle, cultural difference could exists, but should be based on the interaction with a different environment either because of natural or geographical reasons (living in the desert or in the pluvial forest; at the equator or at the north pole) or because different cultures shape their spatial environment in different ways, so that in Morocco people have experience of writing system and calendars that goes from right to left, and in Italy from left to right. The possibility that the everyday experience of differently organized spatial sources can influence the characteristics of our spatio-temporal conceptual mapping is possible even if not necessarily true.

What it seems to be unlikely, based on the classical metaphor theory (Lakoff & Johnson, 1980; 1999), is that arbitrary lexical and grammatical patterns which are language-specific and fruit of a disembodied historical development, could significantly

[102] Source: Núñez & Sweetser, 2006

influence the way we think about time, and other stuff in general. We can give an example. In English it is possible to 'make space' for new dresses on the closet, and 'make time' on your schedule in order to play squash. In Italian, you can still make space (*fare posto*) for new dresses on a closet, but you cannot 'make time' (*fare tempo*), you can just 'find time' (*trovare tempo*) for a new activity. Therefore, Italians and Americans use a different metaphor to talk about time: for Americans time is a commodity than can be made when for Italians time is a commodity that can only be found. Does this linguistic difference corresponds to a difference in the way people think about time? Is it the case, for example, that Americans consider their daily agenda more elastic that Italian people because time can be 'made' and not only 'found'?

Leaving this example aside, the question is quite serius: can accidental differences in linguistic metaphors without any experiential correlate, influence our conceptual costruction of time as conceptual metaphors based on sensory-motor and perceptual experiences do?

This questions, generalized beyond time to the whole domain of thinking, can be placed under the theoretical umbrella of the studies on Linguistic Relativity, a branch of knowledge that try to give an answer to an apparently simple question: do people that speak a different language think in a different way? The answer, as often happens, is less straightforward than the question. We are going to approach the problem of the (presumed) effect of language on thought asking if people that use different spatial metaphors to talk about time, think about time in a different way. Moreover, we will consider also the most radical case: if a natural language do not use (at all!) spatial metaphors to talk about time, are they speakers still using time to think about space? In other words, in the absence of space-time linguistic metaphors, do space-time conceptual metaphors are still existing? According to the classic interpretation of metaphor theory, for which primary metaphors as 'Time is Space' are based on pre-linguistic experience the answer should be positive. We will approach this problem treating the case of the Amondawa, a population of the Brasilian Rain Forest whose language, as it has recently been claimed, [103] do not use spatial metaphor to talk about time.

[103] Sinha et al., *in press*

# 10. Cultural specificity of the direction of the flow of time

The way people use space to talk about time is not necessarily the same way they use space to think about it. In English and many other languages, metaphors suggest that time flows along the sagittal (front-back) axis: deadlines lie *ahead* of us or *behind* us; we can look *forward* to our golden years or look *back* on our greener days. Other languages also make use of the vertical axis to talk about time. In Mandarin Chinese, 'the *up* month' means a month earlier and 'the *down* month' a month later (Boroditsky, 2001; Scott, 1989). By contrast, no known spoken language uses the lateral (left-right) axis to talk about time conventionally, and invented left-right metaphors for time sound nonsensical: Monday comes *before* Tuesday, not *to the left* of Tuesday (Casasanto & Jasmin, 2010; Cienki, 1998).

Despite the total absence of left-right metaphors in spoken language, there is strong evidence that people implicitly associate time with left-right space. Furthermore, the direction in which time flows along people's imaginary timeline varies systematically across cultures. In one study, Tversky, Kugelmass, and Winter (1991) asked children and adults to place stickers on a page to indicate where breakfast and dinner should appear relative to the lunch sticker, in the middle of the page. Whereas English speakers placed breakfast on the left and dinner on the right of lunch, Arabic speakers preferred the opposite arrangement. Fuhrman and Boroditsky (2010) showed a similar pattern in a reaction time (RT) task. English- and Hebrew-speaking participants judged whether the second of two pictures showed an earlier or later stage of an unfolding event. English speakers' judgments were fastest when 'earlier' was mapped to the left button and 'later' to the right, but Hebrew speakers showed the opposite pattern. Ouellet and colleagues (2010) asked Spanish and Hebrew speakers to judge auditorily presented words referring to the past or future with either their left or right hand, and found a similar reversal of the lateral space-time mapping across groups.[104]

[104] Boroditsky & Gaby (2010) has recently reported the interesting case of the community of Pormpuraaw, an Australian Aborigenal population located on the west coast of Cape York peninsula. Like many other languages spoken by small scale populations (see Levinson, 2003), Pormpuraawan languages rely mostly on absolute directions terms (e.g., "north," "south," "east," and "west") instead of relative spatial terms (e.g. "left", "right", "front" and "back") in

These experimental data reflect patterns that can be found in more naturalistic behavior, as well. When English speakers produce co-speech gestures they tend to use the lateral axis for time, much more often than the sagittal axis (Casasanto & Jasmin, 2010; see also Cienki, 1998; Cooperrider & Nunez, 2009). Earlier times are on the left and later times on the right of body-centered space. On the basis of spontaneous gestures, it appears the left-to-right mental timeline may be the strongest space-time mapping in English speakers' minds. Speakers gesture on the lateral axis even when they are using explicitly sagittal space-time metaphors in language, gesturing leftward (not backward), for example, while saying "farther *back*" in time (Casasanto & Jasmin, 2010). Spanish speakers' gestures follow a similar pattern as English speakers', but native Arabic speakers' spontaneous gestures tend to show the reverse space-time mapping (Romàn, Casasanto, & Santiago, in preparation).

Across cultures, the direction in which time flows along the mental timeline varies predictably with the orthography of the dominant language. Time flows rightward in cultures whose literate members use a left-to-right orthography and leftward in cultures that use a right-to-left orthography. Yet, despite this clear

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describing and indicate spatial relationships ad orientation. In Pormpuaraaw is normal to say things like "move your cup over to the north-northwest a little bit" or "the boy standing to the south of Mary is my brother" (Boroditsky & Gaby, 2010). This linguistic use correspond to a particularly developed sense of orientation according to the absolute cardinal points:

"In Kuuk Thaayorre (one of the languages included in this study), to say hello, one says, 'Where are you going?' and an appropriate response would be, 'a long way to the south- southwest.' Thus, if you do not know which way is which, you literally cannot get past hello. Previous work has documented that speakers of such languages do indeed stay oriented, show precision in spontaneous co-speech gesture, and exhibit remarkable skill in dead reckoning" (Boroditsky & Gaby, 2010, p. 2)

Does this peculiar representation of spatial direction correspond to a peculiar representation on temporal direction? To find out, Boroditsky & Gaby tested American and Pormpuraawans subjects in simple temporal tasks. In one of this, for example, they had to put in order a temporal progression (e.g. a man at different ages) arranging a set of cards. American subjects, as predictable, arranged the cards from left to right, without regard for the cardinal orientation. Pormpuraawans, instead, arrange the cards according to cardinal directions: east to west. So that, time flows from left to right when one is facing south, from right to left when one is facing north, toward the body when one is facing east, and away from the body when one is facing west.
The author suggested that the east-to-west time orientation is related to the motion of the sun, so that a spatial trajectory that can be used to mark the different times of a day (morning- noon- evening) is abstracted and used (metonymically, as Lakoff would say) to lay out time at different scales, from events and changes of a few seconds duration (an apple falling from a tree) to those that take years (a young boy becoming an old man). A process of abstraction that curiously remember the solution to the enigma of the sphinx, solved by Oedipus.

correlation, it is not clear what is the role of reading and writing in a particular direction in shaping the implicit space-time mapping which emerge from laboratory experimentation and the observation of spontaneous gestures.

## 10.1 A causal role for orthography?

Distinguishing the possible experiential bases of our mental representations is often difficult because convergent streams of physical and social experience appear mutually inextricable (Casasanto, 2009). In the case of the sagittal mental timeline, for example, the front-back mapping of time could become entrenched in individual's minds due to perceptuo-motor experiences, as they move 'forward' in both space and time while crawling, walking, or driving through the physical environment in the canonical frontward direction (see Clark, 1973). Alternatively, the front-back mental timeline could arise due to exposure to linguistic metaphors (see Boroditsky, 1999; Núñez & Sweetser, 2006; and next chapter), or due to some combination of perceptuo-motor and linguistic experiences.

The left-right mapping of time provides a valuable testbed for investigating the experiential origins of our mental representations because the directionality of the lateral timeline could *only* arise as a function of cultural experiences. Its direction could not be fixed by spoken metaphors, which as discussed above, only encode front-back motion. A general association between progress through space and progress through time could be learned from regularities in the physical world: As people and things travel farther through space, more time passes (Casasanto, 2010; Casasanto & Boroditsky, 2008; Merritt, Casasanto, & Brannon, 2010). But the physical evidence for this space-time association is not direction-specific. More elapsed time correlates with more progress through space in any direction. It is unlikely that regularities in people's perceptuo-motor interactions with the natural world could lead them to create a space-time mapping with a particular left-right directionality. Left-right conventions for representing events develop in culture-specific media such as films (Santiago, et al., 2008), but it is not the case that earlier events occur on the left and later events on the right in nature.

Having identified 'culture' as the source of the left-right mental timeline's directionality, it is still unclear which cultural practices might shape people's implicit representations of time, and on what timescale. Cultural practices tend to covary. Groups who write from left to right often spatialize time on calendars and graphs from left to right, as well. Directionality in both orthography and in thought could arise due to directionality in material artifacts like calendars (whether a grid on a piece of paper, knots on a string, notches on a branch, etc.) or other graphic devices for keeping track of time or number (e.g., a solar clock, an abacus), which often precede the widespread use of alphabetic writing systems historically (Dehaene, 1999; Tversky, et al., in press). Furthermore, even if orthography contributes to the standardization of graphic representations of time on the timescale of cultural development, there is no guarantee that it contributes to the stabilization of implicit space-time mappings on the timescale of individual cognitive development. Culture-specific timelines could be transmitted to new learners via other media such as gestures, which are earlier acquired and more universal than reading and writing. But also other graphic representation of events succession, like temporal sequences in movies and cartoons, calendars, or sequences in books used for story telling, might play a fundamental role in determining the direction of our implicit time-line. Given the fact that also preschool children, presumably with a little experience of reading and writing, show a preferred temporal direction according to their own culture (Tversky et al., 1991), we could think that reading/writing experience can assume a central role in shaping the implicit cognitive mapping which underlie the unconscious representation of the time line, but it is probably not necessary.

based on the data reviewed above, it is not possible to determine whether experience with orthography (or any other cultural practice) plays a causal role in determining and consolidating the specifics of the implicit space-time mappings in individuals' minds.

Here we performed two sets of experimental interventions to determine whether experience with orthography is sufficient to determine, or at least affect or modulate, the direction and orientation of people's implicit mental timelines. Native Dutch speakers were assigned to perform one of five versions of a space-time congruity task, with instructions and stimuli presented in either standard or mirror reversed orthography. To preview these experiments, in the canonical version (Experiment 1a) participants saw past-oriented phrases (e.g. a year before) and future-oriented phrases (e.g. a day after) written in standard Dutch orthography (fig. 1a). As soon as each phrase appeared participants pressed a colored button (located on the left or right of a keyboard, counterbalanced across blocks) to indicate whether the phrase referred to an earlier or a later time. The left-right position of the keys was irrelevant to the earlier-later judgment. Still, we predicted that if Dutch speakers implicitly conceptualize time as flowing rightward when exposed to standard Dutch orthography, they should be faster to judge the temporal reference of phrases when their responses are consistent with the left-to-right flow of time. In Experiment 2b, the task was identical but the instructions and stimuli were shown in mirror-reversed text (fig. 1b). Reading requires scanning the page in a particular direction. Normally for Dutch speakers, reading each line of a text requires moving the eyes gradually from the left to the right side of the page or the computer screen. As such, moving rightward in space is tightly coupled with 'moving' later in time. We reasoned that if the habit of reading from left to right contributes to an implicit left-to-right mapping of time in readers' minds, then practice reading in the opposite direction should weaken and eventually reverse this mapping. Experiment 1c investigated whether the influence of orthography on time representations is only an online effect found during reading, or whether reading experience can modify implicit associations between space and time in memory.

## 10.2 Experiment 1: Standard orthography

In Experiment 1a, all instructions and stimuli were presented in standard Dutch orthography. We conducted this experiment to validate the use of this space-time congruity paradigm in native Dutch speakers, and to provide a comparison group for the mirror-reading group (Experiment 1b).

### 10.2.1. Methods

Participants. Native Dutch speakers (N=54) from the Radboud University community performed Experiment 1a in exchange for payment. Data were collected in two cohorts, providing an internal replication of this experiment. Participants from Cohort 2 also performed Experiment 1c (see below). Since a similar pattern of results was observed in Cohort 1 (n=30) and Cohort 2 (n=24), the data were combined in the analyses reported here.

Materials

*Stimuli.* Temporal phrases were constructed in Dutch, each with 3 words. The first word was an indefinite article, the second word a temporal interval, and the third word an adverbial indicating a 'direction' in time. Twelve temporal intervals were fully crossed with four adverbials to produce 48 temporal phrases (see Appendix A for Dutch stimuli English translations). Half of the phrases referred to an earlier (past-oriented) interval of time, and the other half referred to a later (future-oriented) interval. Two of the adverbials were spatial terms used metaphorically (tr. *before*, *after*), and the other two were purely temporal terms with similar meanings (tr. *earlier*, *later*). Phrases were presented in the center of a Macintosh laptop screen (resolution=1024x768), in black 48-point Arial font, on a white background.

*Apparatus.* Participants were seated at a desk. Two A4 Xerox paper boxes were stacked on the desk, and a laptop computer was secured on top of them, to raise the screen to approximately the participants' eye-level. A standard USB keyboard was mounted horizontally on the front face of the upper box, with the keys facing the participant, at about shoulder level. The keyboard was covered with a sheet of black plastic with holes that exposed only the three keys needed for responses: the "A" key on the left, the "apostrophe" key on the right, and the "H" hey in the middle. The middle key was aligned with the center of the laptop screen, and the left and right keys were equidistant from it. The left key was covered with a blue sticker and the right key a red sticker, or vice versa, with the key colors counterbalanced across subjects.

Procedure The experiment consisted of two blocks. In each block, each of the 48 temporal phrases was presented once, for a total of 96 trials. Written instructions appeared on the screen before each block. In one of the blocks, participants were instructed that as soon as each phrase appeared, they should press the blue button if the phrase referred to an interval of time in the past (e.g., a week earlier) and the red button if it referred to an interval of time in the future (e.g., a week later). In the other block, the mapping between the red/blue keys and pastward/futureward phrases was reversed. To ensure that participants remembered the correct color-time mapping, after reading the instructions they were required to rehearse the correct color-time mapping aloud 5 times, before each block (e.g., "Say aloud, past=blue, past=blue, past=blue, etc.; future=red, future=red, future=red, etc.)

At the beginning of each trial the word 'ready' appeared in the center of the screen and remained there until the participant pressed the middle white button. 'Ready' was then replaced by a fixation cross. Participants were instructed to hold down the white button for as long as the fixation was shown. Its duration was varied randomly from 300-450 ms, in 50 ms increments, to make its duration unpredictable and to discourage anticipatory movements. The fixation was then replaced by one of the 48 temporal phrases. Participants were instructed to press the colored button corresponding to the temporal reference of the phrase as quickly and accurately as possible. The phrase remained on the screen until the participant responded, at which time it was replaced by the 'ready' message to begin the next trial.

Participants pressed buttons with the index finger of the dominant (writing) hand. To ensure they would used the same hand for both rightward and leftward responses, participants were required to sit on their non-dominant hand. The spatial direction of responses was never mentioned, but one colored button was on the right and the other on the left of the middle white button. Therefore, in one block pressing the correctly colored button called for a movement that was congruent with the space-time mapping encoded in standard Dutch orthography (e.g., pressing the blue button for a pastward phrase when the blue button was on the left); in the other block pressing the correctly colored button called for an incongruent movement (e.g., pressing the blue button for a futureward phrase when the blue button was on the left). The order of congruent-movement and incongruent-movement blocks was counterbalanced across participants. The space-time congruity effect was computed for each participant by comparing response times during Congruent and Incongruent responses (between-blocks, within-items). Testing lasted about 10 minutes.

### 10.2.2 Results and Discussion

Participants pressed the correct button on 97% (±1%) of trials. Accuracy was higher for orthography-congruent responses (i.e., responses congruent with the rightward flow of time; Accuracy = 98% ±1%) compared with orthography-incongruent responses (Accuracy = 95% ±1%; Difference = 3%; $t(53)=4.06$, $p=.0002$). RTs were analyzed only for accurate responses. This resulted in the removal of 3% of the data.

Responses greater than 5000 ms were also excluded, which resulted in the removal of 0.03% of the accurate trials.

RTs were analyzed using a linear regression model with Subjects and Items as repeated random factors. Of primary interest, there was a highly significant effect of Congruity (Orthography-Congruent RTs, Orthography-Incongruent RTs). For the same temporal phrases, responses were nearly 200 milliseconds faster when the key mapping was consistent with the rightward flow of time than when it was reversed (Wald $\chi^2$=185.86, df=1, p=.0001; fig. 15, left columns).

We conducted two sets of exploratory analyses to determine how the semantics of the temporal phrases influenced the congruity effect. For half of the stimulus phrases the adverbials were space-time metaphors (Metaphorical Spatial Language: tr. *before*, *after*), but for the other half the adverbials were purely temporal words with no spatial meanings (Non-Spatial Language: tr. *earlier*, *later*). The congruity effects were significant in each category of stimuli, considered separately (Metaphorical Spatial Language congruity effect = 192 ms, Wald $\chi^2$=118.55, df=1, p=.0001; Non-Spatial Language congruity effect = 147 ms, Wald $\chi^2$=70.84, df=1, p=.0001). However, the congruity effect was stronger for Metaphorical Spatial Language stimuli, as indicated by an interaction of Congruity with Language Type (Wald $\chi^2$=191.13, df=3, p=.0001). From one perspective it seems natural that the space-time congruity effect should be enhanced when participants are tested using space-time metaphors in language. However, this finding is also surprising given that space-time metaphors like *before* and *after* are typically analyzed as implying a spatialization of time on the sagittal axis, not the lateral axis (e.g., Clark, 1973). The present data suggest that these 'sagittal' metaphors in language may, in fact, cue comprehenders to construct lateral representations of time, corroborating a pattern found in spontaneous gestures where speakers tend to gesture laterally for time even when using explicitly front-back language (Casasanto & Jasmin, 2010).

In a second exploratory analysis, we found a relationship between the duration of the temporal interval mentioned in the stimulus and the magnitude of the congruity effect, according to a non-parametric correlation (Spearman's rho = -.57, N=12, p=.05). Congruity effects were larger for short intervals (e.g., second) and smaller for long intervals (e.g., millennium). The difference in congruity effects cannot be accounted for by the overall differences in RT between short and long intervals, as no significant relationship was found between the durations of the intervals and overall RT (Spearman's rho = -.15, N=12, *ns*). This pattern was unexpected, and has not been reported previously, to our knowledge. On one possible interpretation, brief events may be easier to conceptualize as 'objects' in time compared with extended events, and therefore easier to spatialize implicitly as point on a mental timeline.

To summarize the main result of Experiment 1a, participants responded fastest when the mapping between the color of the buttons and the temporal reference of the phrases required leftward movements for past-oriented phrases and rightward movements future-oriented phrases. This space-time congruity effect is similar to effects found previously in English and Spanish speakers (e.g., Torralbo, et al., 2006; Weger & Pratt, 2008). We are not aware of previous studies showing this effect in Dutch speakers, but given the correlation between writing direction and the direction of the space-time mappings across cultures, we expected that Dutch speakers would perform similarly to speakers of other languages that use a Roman alphabet.

Having found clear evidence for the implicit space-time mapping typically found in members of left-to-right reading cultures, we proceeded to test effects of exposure to an orthography that requires people to progress along a spatio-temporal continuum in the opposite direction as they read or write.

## 10.3 Experiment 1b: Mirror-reversed orthography

To test whether orthography can play a causal role in determining the direction of the mental timeline, we replicated Experiment 1a in a new group of participants using stimuli and instructions presented in mirror-reversed font.

### 10.3.1 Methods

Participants. A new sample of native Dutch speakers (N=54) from the Radboud University community performed Experiment 1b in exchange for payment. Data were collected in two cohorts, providing an internal replication of this experiment. Participants from Cohort 2 also performed Experiment 2 (see below). Since a similar pattern of results was observed in Cohort 1 (n=30) and Cohort 2 (n=24), the data were combined in the analyses reported here.

Materials and Procedure. All materials and procedures were identical to Experiment 1a, except that the instructions and stimuli were presented in mirror-reversed text.

### 10.3.2 Results and Discussion

Participants pressed the correct button on 97% (±1%) of trials. Accuracy for orthography-congruent responses (i.e., responses congruent with the *leftward* flow of time) was 98% (±1%), and did not differ significantly from accuracy for orthography-incongruent responses (Accuracy = 96% ±1%; Difference = 2%; t(53)=1.81, *ns*). RTs were analyzed only for accurate responses. This resulted in the removal of 3% of the data. Responses greater than 5000 ms were also excluded, which resulted in the removal of 2% of the accurate trials.

RTs were analyzed using a linear regression model with Subjects and Items as repeated random factors. Of primary interest, overall there was no effect of congruity with the leftward flow of time (or with the rightward flow of time; Wald $\chi^2$=0.005, df=1, p=.95; fig. 15, right columns).

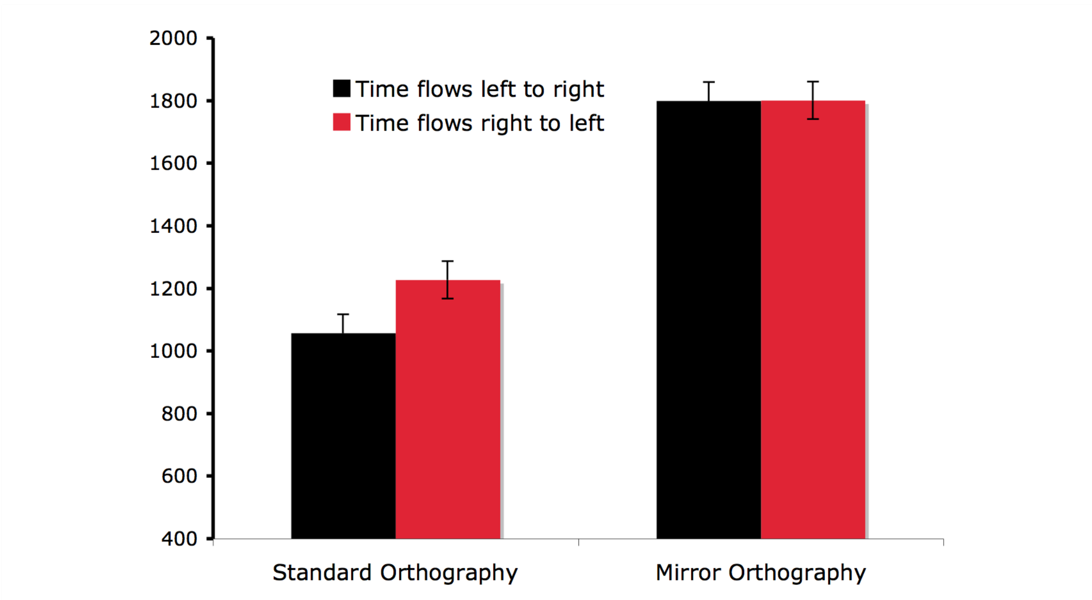


Fig.15

Planned comparisons showed a significant difference between the space-time congruity effects found in Experiments 1a versus 1b, as indicated by a highly significant interaction of Congruity (Orthography-Congruent RTs, Orthography-Incongruent RTs) with Orthography (Standard Orthography, Mirror-Reversed Orthography; Wald $\chi^2$=37.19, df=1, p=.0001), as well as a main effect of congruity (Wald $\chi^2$=38.68, df=1, p=.0001) and a main effect of Orthography (Wald $\chi^2$=1747.46, df=1, p=.0001). The main effect of orthography was expected (people were faster to respond when stimuli are presented in Standard rather than Mirror-Reversed text), though not of interest with respect to the hypothesized effect of orthography on time representation. The critical Congruity x Orthography interaction indicates that the space-time congruity effect normally found in members of left-to-right reading cultures was extinguished after brief exposure to mirror-reversed orthography.

As analyzed so far, however, the data have not provided any evidence that experience reading a right-to-left orthography can *reverse* the flow of time in Dutch speakers' minds. Since the right-to-left mental timeline found previously in Hebrew and Arabic speakers is in direct opposition to the left-to-right timeline found in cultures with Roman alphabets, we expected that effects of 'training' with mirror-reversed text might not be evident immediately. The experiment was designed to allow direct comparison of the congruity effect during the first presentation of the 48 stimuli (in Block 1) and the second presentation of the same stimuli (Block 2). In further planned analyses, we compared congruity effects between the first and second blocks of Experiment 1a (fig. 16a) and Experiment 1b (fig. 16b), and then compared the effects of Congruity and Block across experiments.

In Experiment 1a, the congruity effect was remarkably consistent across blocks. There was a main effect of Block (Wald $\chi^2$=22.92, df=1, p=.0001), indicating that participants got faster with practice judging the stimuli, and a strong main effect of Congruity (Wald $\chi^2$=186.51, df=1, p=.0001), but there was no interaction of Congruity x Block (Wald $\chi^2$=0.47, df=1, p=.50; fig. 3a). By contrast, in Experiment 3b, although there was a main effect of Block indicating that participants got faster with practice (Wald $\chi^2$=659.61, df=1, p=.0001), there was no main effect of congruity (Wald $\chi^2$=0.75, df=1, p=.39) and importantly, there was a significant Congruity x Block interaction (Wald $\chi^2$=70.62, df=1, p=.0001). Most importantly, across experiments there was a highly significant 3-way interaction of Congruity x Block x Orthography (Wald $\chi^2$=2459.52, df=1, p=.0001).

a) Standard Orthography b) Mirror Orthography

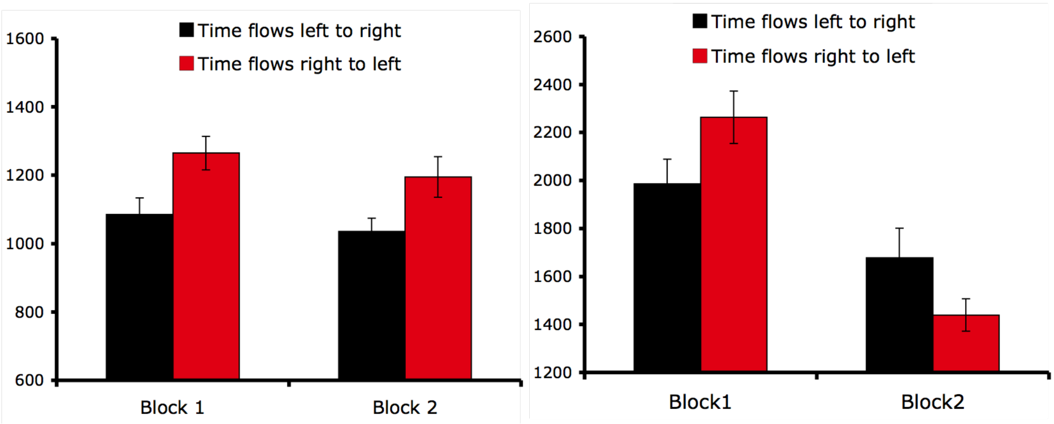


Fig 16

Planned pairwise comparisons evaluated the congruity effects in each block of each experiment. In Experiment 1a, orthography-congruent responses were faster than orthography-incongruent responses in each block considered separately (Block 1 congruity effect: Wald $\chi^2$=92.19, df=1, p=.0001; fig 3a, left columns; Block 2 congruity effect: Wald $\chi^2$=65.14, df=1, p=.0001; fig 3a, right columns). In Experiment 1b, *orthography-incongruent* responses were fastest for the first block (Block 1 congruity effect: Wald $\chi^2$=40.18, df=1, p=.0001; fig 3b, left columns) showing the persistence of the Dutch speaker's default timeline at the beginning of the experiment, but by the second block orthography-congruent responses were fastest, indicating a reversal in participants' implicit mental timelines (Block 2 congruity effect: Wald $\chi^2$=50.44, df=1, p=.0001; fig 3b, right columns).

To summarize the main findings of Experiments 1a-b, initially during the first block of trials, Dutch speakers showed a congruity effect consistent with the rightward flow of time both when tested with standard orthography (1a) and when tested with mirror-reversed orthography (1b). This pattern changed, however, by the second block of trials in Experiment 1b. After about 5 minutes of practice reading a right-to-left orthography, participants' implicit mental timeline was completely reversed.

## 10.4 Experiment 2: Lasting effects of orthographic experience?

Is the influence of orthography on the mental timeline an online effect, found only while people are reading standard or mirror-reversed orthography, or are there also lasting consequences of exposure to a new orthography for subsequent time representation?

On one possibility, the influence of orthography on the mental timeline that we observed in Experiment 1b might only be present while participants are making directed eye movements during reading. In this case, the RT effects we found could be a direct consequence of congruity between ocular and manual motor actions. When reading requires the eyes to move leftward through both space and time, then leftward movements of the hand are facilitated for 'later' responses, relative to rightward hand movements. Alternatively, however, the habit of moving leftward in space while moving later in time during reading could change implicit space-time associations in memory, producing 'offline' effects of orthography. Even if directed eye movements are responsible for creating the link between orthography and time, associations in memory could last longer than the reading or writing experiences needed to establish them, eventually giving rise to culture-specific habits of time representation.

To find out whether orthography-based differences in the mental timeline persist beyond the experience of reading in one direction or the other, we conducted a follow-up experiment testing for space-time congruity effects with auditorily presented stimuli.

### 10.4.1 Methods

Participants. Native Dutch speakers (N=48) from the Radboud University community performed Experiment 1c in exchange for payment. These participants had constituted Cohort 2 of Experiments 1a (n=24) and 1b (n=24). Participants performed Experiment 2 a few minutes after completing either 1a or 1b. As such, half of the participants in 2 had been recently exposed to standard orthography and the other half to mirror-reversed orthography.

Materials

*Stimuli.* We selected 52 celebrities, half of whom became popular after 1990 (e.g., Barack Obama, Lady Gaga), and the other half of whom became famous before 1980 (e.g., Charlie Chaplin, Marilyn Monroe; see Appendix B). The name of each celebrity was recorded as a sound file in a soundproof room by native Dutch native speaker, who also recorded the instructions.

*Apparatus.* Participants were seated at a desk. A laptop computer was placed in the middle of the desk, with the screen approximately 50 cm from the participant. The screen remained black for the duration of the experiment. All instructions and stimuli were presented auditorily from the laptop's built-in loudspeakers, located symmetrically on the left and right of the screen.

Procedure .The procedure was adapted from Experiment 1 of Weger and Pratt (2008). Instructions were presented auditorily. Each of the 52 names (4 practice items and 48 target items) was presented twice, once in each of 2 blocks, for a total of 104 trials. After hearing each name participants indicated whether the celebrity became popular before or after they (the participants) were born by pressing either the "C" key (on the left of the keyboard) using the left index finger or the "M" key (on the right of the keyboard) using the right index finger. The "C" key indicated an 'old' (pre-1980) celebrity and the "M" key a 'new' (post-1990) celebrity for one block of trials, consistent with the rightward flow of time. The key mapping was reversed for the other block of trials, with the order of blocks counterbalanced across participants. After each response there was a delay that varied randomly between 300-450 ms in 50 ms increments, followed by the next stimulus.

A space-time congruity effect was computed for each subject by comparing response times during button presses that were Congruent and Incongruent with the orthography in the experiment they had performed previously (i.e., standard orthography in Experiment 1a or mirror-reversed orthography in Experiment 1b). Testing lasted about 10 minutes.

### 10.4.2 Results and Discussion

Participants pressed the correct button on 89% (±2%) of trials. Accuracy was 90% (±2%) for 'Standard-Trained' participants who had done Experiment 1a, and did not differ significantly from accuracy in 'Mirror-Trained' participants who had done Experiment 1b (Accuracy = 88% ±2%; Difference = 2%; $t(46)=0.99$, *ns*). RTs were analyzed only for accurate responses. This resulted in the removal of 11% of the data.

Responses greater than 5000 ms were also excluded, which resulted in the removal of 0.7% of the accurate trials.

RTs were analyzed using a linear regression model with Subjects and Items as repeated random factors. Of primary interest, there was a highly significant space-time congruity effect in the Standard-Trained participants, showing an RT advantage for button presses consistent with the rightward flow of time (i.e., left button for Old celebrities, right button for New celebrities: Wald $\chi^2$=31.22, df=1, p=.0001; fig. 4, left columns). By contrast in Mirror-Trained participants, there was no space-time congruity effect (Wald $\chi^2$=2.25, df=1, *ns*; fig. 17, right columns). Crucially, there was an interaction of Congruity (Orthography-Congruent RTs, Orthography-Incongruent RTs) with Training (Standard Training, Mirror Training; Wald $\chi^2$=7.24, df=1, p=.007). There was also a main effect of Congruity (Wald $\chi^2$=23.96, df=1, p=.0001), and a marginally significant main effect of training (Wald $\chi^2$=3.29, df=1, p=.07), driven by the slow RTs in the Incongruent condition for Standard-Trained participants.

To summarize the main finding of Experiment 1c, exposure to mirror-reversed orthography affected participants' subsequent time representations. The influence of reading direction on time representation is not only an online effect. Participants who had been exposed to standard orthography in Experiment 1a showed a standard RT congruity effect, consistent with the rightward flow of time, even when they were tested with auditory stimuli. By contrast, participants who had been exposed to mirror-reversed orthography in Experiment 1b showed no significant space-time congruity effect. The effect of exposure to a new orthography extended beyond the training episode, suggesting that reading experience influenced associations between space and time in memory.

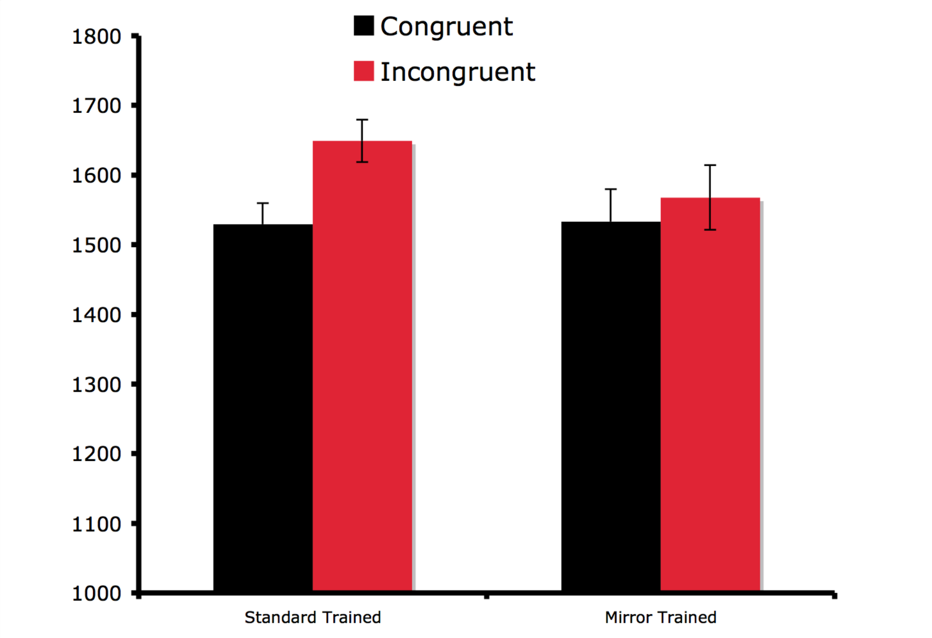


Fig.17: Experiment 2: Lasting effects of orthographic experience

The standard space-time congruity effect was reversed during the second half of Experiment 1b, but subsequently it was only extinguished (not reversed) in these participants, in Experiment 1c. We consider two possible explanations for the absence of any significant congruity effect in the mirror-trained participants in 1c. On one possibility, perhaps the residual effect of mirror-reading was sufficient to nullify the dominant space-time mapping in participants' memories, but not sufficient to replace it with the new right-to-left mapping. On this account, participants were left without any active 'mental metaphor' linking spatial and temporal succession (Casasanto, 2008, 2009, 2010). Yet, if this were the case, the reaction times in the mirror-trained participants should be intermediate between the Congruent and Incongruent responses of the standard orthography-trained participants. This was not the case; rather, RTs for both the Congruent and Incongruent responses in mirror-trained participants were statistically indistinguishable from the Congruent responses in standard-trained participants.

This suggests an alternative possibility. The amount of mirror-training that the participants in Experiment 1b received was sufficient to make the right-to-left space-time association active in memory, in addition to the standard left-to-right mapping. On this account, there was no significant congruity effect in Exp. 2 for mirror-trained participants because there were no incongruent trials: for one block of trials the button presses were consistent with the default left-to-right space-time mapping, and for the other block button presses were consistent with the newly-strengthened right-to-left mapping. The possibility that participants might be able to switch rapidly between two opposing space-time mappings will be considered further in the General Discussion.

On either account of these data, it should be possible to give participants enough training with mirror-reversed orthography to eventually reverse their space-time mapping (not just neutralize it) 'offline' as well as online during reading. This proposal awaits further experimental test.

## 10.5 General Discussion

It is now well established that people activate implicit associations between space and time when processing temporal language, and that the specifics of these associations vary systematically across cultures (Fuhrman & Boroditsky, 2010; Ouellet, et al. 2010; Tverksy, Kugelmass, & Winter, 1991). Since time is not associated with left-right space in any known linguistic metaphors, it is unlikely that these culture-specific mappings are learned through experience with spoken language. Here we tested whether orthography can play a causal role in fixing the direction in which time flows along the imaginary mental timeline. Experiment 1 showed that, when exposed to temporal phrases presented in standard left-to right orthography, Dutch speakers implicitly associated earlier time intervals with leftward movements and later time intervals with rightward movements, consistent with previous findings in members of other cultures that use the Roman writing system.

However, when exposed to several minutes of mirror-reversed writing, Dutch participants began to show space-time congruity effects that revealed a reversal of their normally dominant implicit space-time mapping. By the second time they were judging each of the 48 temporal phrases (Block 2 of Experiment 1b), participants were faster to make responses when key presses associated earlier events with rightward movements and later events with leftward movements -- a pattern observed previously in speakers of Hebrew, which is written from right to left. It appears that experience reading a right-to-left orthography (which requires the reader to 'progress' leftward across the screen with his/her eyes) is sufficient to reverse the flow of time in the reader's mind, at least transiently.

Although this rapid retraining of a space-time association stored in long-term memory may seem surprising, it is not unprecedented. In one study, Boroditsky (2001; see also next chapter) found that horizontal spatial primes facilitated English speakers' judgments of temporal sentences (e.g., April comes earlier than May) more than vertical primes did, but found the opposite pattern in Mandarin speakers, consistent with the difference between these languages in the prevalence of horizontal and vertical metaphors for time. To test whether linguistic experience could affect these mappings, she trained a new group of English speakers to use Mandarin-like vertical spatial metaphors for time. After brief training, English speakers showed a pattern of priming similar to native Mandarin speakers.

In a test of a different set of space-time metaphors Casasanto (2008) and colleagues showed that when English and Greek speakers perform non-linguistic duration reproduction tasks, they show language-specific patterns of cross-dimensional interference from space. Whereas English speakers have a harder time screening out interference from (1-dimensional) spatial distance, Greek speakers have more difficulty screening out interference of (3-dimensional) volume. This pattern was predicted based on the relative prevalence and productivity of distance and volume metaphors for duration across languages (e.g., a long time (like a long rope); a large amount of time (like a large amount of water)). To find out whether using volume metaphors could cause the volume-interference found in Greeks, US English speakers were trained to use Greek-like volume metaphors for time. Results showed that after one brief (but concentrated) training session, English participants showed a pattern of cross-dimensional interference from volume in a low-level psychophysical task that was statistically indistinguishable from the pattern seen in native Greek speakers.

Time is not the only domain that appears to be mentally represented, in part, through spatial metaphors (which may or may not correspond to linguistic metaphors). Emotional valence is also spatialized on a left-right axis: whereas right-handers tend to associate the right hand and the right side of space with positive things and the left with bad, left-handers show the opposite set of implicit associations (Casasanto, 2009b). It was proposed that this mapping arises due to asymmetries in motor fluency: people like things on their dominant side better because they can interact with things on that side more easily. To test this proposal, Casasanto (2009c) asked right-handers to perform a 2-part training task. In the first part, they arranged dominoes according to a symmetrical pattern on a tabletop, standing them on end, moving both hands in synchrony. The challenge was that they were randomly assigned to wear a bulky ski glove one hand or the other while performing the task, which either enhanced their natural right-handedness or made them temporarily more skillful with their left hand.

After 12 minutes of this asymmetric motor experience, participants were taken to a different room by a different experimenter for some ostensibly unrelated questionnaire studies, one of which tested implicit associations between space and valence. This questionnaire was shown previously to produce distinctive patterns of judgments in right- and left-handers (Casasanto, 2009b). Participants whose training experience preserved their natural dominance showed the typical right-handers' pattern. But participants who had worn the skiglove on their right hand during training, becoming transiently left-handed, produced a pattern of responses that was indistinguishable from natural lefties'.

We are aware of one training study that manipulated writing direction in order to test a role for orthography in the spatial representation of gender and agency. Several studies suggest that males (seen as more agentive) tend to be represented to the left of females in the minds of people who speak left-to-right languages like English, but not for speakers of right-to-left languages like Arabic (Suitner, 2009). Yet, Suitner (2009) showed that this spatial bias can be nullified in speakers of Italian who are trained to perform a leftward writing exercise, reversing not only their habitual writing direction but also their habitual associations of gender, agency, and space.

How enduring are these training effects? Presumably, without further reinforcement of the new habits, participants who show rapid training effects will also revert to their long-term habits rapidly. Exactly how soon remains a question for further research. However, our follow up experiment show that the effect of the training persists after the training itself, suggesting that the reversing of the implicit mapping it is not only an on-line effect that goes away once the exposure to the mirror orthography ceases.

How best to characterize the learning mechanisms that afford this representational plasticity remains another open question. It may be fruitful to consider the changes participants undergo in Experiment 1b in terms of a hierarchical Bayesian model (Kemp et al., 2007). To sketch this suggestion briefly, people's associations between space and time could be characterized as intuitive hypotheses. Based on ordinary reading experience, Dutch speakers form the hypothesis that by default events unfold from left to right. Yet after training, they appear to entertain the hypothesis that events unfold from right to left.

To explain how participants can switch from one hypothesis to a contradictory hypothesis (and presumably switch back) so quickly, it may help to posit that they also entertain a more enduring overhypothesis, of which both the 'Dutch-like' and 'Arabic-like' space-time associations are specific instances. The overhypothesis could be that time is associated with motion along a linear path. Such a belief would be well supported by observable correlations in the physical world: spatial succession is a reliable index of temporal succession.

Consistent with this proposal, we suggest that if orthography is responsible for determining the direction in which time flows along people's left-right mental timelines, this directional mapping likely builds upon a prior less-specific space-time association, which arises (either in developmental or evolutionary time) from space-time correlations that have no particular directionality: On any trajectory, it is the case that as a moving object travels farther, more time passes. The hierarchical model can help to explain how 'mental metaphors' linking space-time can be universal at one level of level of description but culture-specific at another.

## 10.6 Conclusions

In experimental study presented above, the goal was to test the sufficiency of a proposed cause of cross-cultural differences. The total reversal of the congruity effect as a function of reading experience demonstrates that orthography can, indeed, influence the implicit spatial representation of time.

In this chapter, we have seen how our representation of time can be based on metaphorical constructions that are not represented at the level of verbal language. A left-right lateral representation of time clearly emerge in spontaneous gestures (Casasanto & Jasmin, 2010) and is automatically activated when people are asked to think about time in terms of past and future events. Beyond the sensorimotor experience of moving in space, also the everyday exposure of orthographical patterns, and probably graphical representations of time, can become the basis of culture-specific metaphorical conceptualization of time. Although well established in culture, constantly represented in temporal artifacts like calendars and naturally accessed during co-speech gestures and temporal reasoning, such a culture-specific mapping is highly flexible and context-depended. The limits and the possibilities of the contextual adaptation of this and other metaphorical representation of time constitute open questions for future research.

# 11. Can language shape our representation of time?

Can the way people talk about time shape the way they think about it? Different spatial metaphors for temporal expression in different natural languages can significantly influence temporal thought independently of other cultural aspects? More broadly: do people that speak different languages think in a different way?

## 11.1 The principle of linguistic relativity

In the world there are more that 6000 languages, and often they drastically differ from each other. Languages can differ at the level of lexicon, grammar, phonology, syntax, etc. For example, if we want to say that "the cat ate the mice", in Eglish we have to specify the temporal tense (in this case the action took place in the past), but we can avoid to do it if we speak Mandarin. In Italian, we have also to specify if the cat is male or female, and in Russian if he has eaten all the mice or just some of them. In Turkish, we have also to specify if we have witnessed the event or if someone other told us what happened (See Boroditsky, 2003). Could these grammatical differences affect the vision of the world of the member of a particular linguistic community?

For many centuries the discussion about the relationship between language, thought and reality has been influenced by the Aristotelian tradition according to which it exists an evident parallelism between the language and the ontological reality that it describes. Briefly, according to this thought, it exists only one vision of the world that can be defined 'true' or 'correct', and language describes (or should describe) precisely the logic relations between the elements of knowledge and the objects of the real world. However, the vision of the world it is not determined by the language one speak (althought the opposite is true), but by the relationship between the reality and its mental representation. As St. Thomas clearly pointed out, *veritas est adaequatio rei et intellectus*.

It is during the XVIII century, when the rationalistic conception according to which language reflect logical thought was seriously challenged, that a more relativistic approach began to grow. It is during these years that was coined the expression 'genio delle lingue'[105] (e.g. Melchiorre Casarotti, *Saggio su la filosofia delle lingue*,1785), which basically represents the original character of an idiom and a community, a romantic concept which has contributed to create the presuppositions for the identification language-nation typical of the nationalism of the late XVIII century in Europe. Advocates of this relativistic approach were, among other, de Condillac, Leibniz and Herder, but we owe the first complete and argufied formulation of what has been called *linguistic determinism*, to the poliedric scholar Wilhem von Humboldt (1767-1835). Von Humboldt suggested that our vision of the world (weltanschauung) is determined by language. He described the act of thinking as the tireless activity of dividing and organizing the data that come from the sensible experience, and he suggested that this capacity of segmentation and organization is permitted by language (an idea taken up also by De Saussure[106]). To a different language corresponds a different segmentation of the reality and, therefore, a different *weltanschauung*.

Nevertheless, apart from Saussure (to some extent), the linguistic of the 19th century took a different approach, and we have to wait until the beginning of the last century to see the relativistic approach reappearing in the academic discussions. The introduction of the *principle of linguistic relativity* in the modern linguistic is strictly associated with the names of a chemical engineer with a passion for linguistics, Benjamin Whorf, and his professor of linguistics Edward Sapir. They gave the name to the famous *Sapir-Whorf Hypothesis*, even though the paternity of the *principle of linguistic relativity*[107] is to ascribe to the only Whorf, while Sapir had a more moderate opinion.

This is probably the most famous Whorf's quotation:

[105] 'Genius of languages'
[106] « … notre pensée n'est qu'une masse amorphe et indistincte. Philosophes et linguistes ne sont toujours accordés a reconnaître que, sans le secours des signes, nous serions incapables de distinguer deux idées d'une facon claire et constante. Prise en elle-même, la pensée est comme une nébuleuse où rien n'est nécessairement délimité. Il n'y a pas d'idées préétablies, et rien n'est distinct avant l'apparition de la langue » (Saussure 1972: 155-156).
[107] The appellation 'Sapir-Whorf Hypothesis' has never been used neither by Sapir nor by Whorf. Whorf have always spoken about a 'new principle of linguistic relativity', and he has never used the term 'hypothesis'. As suggested by the word itself, a principle is point of departure, a necessary origin for having successive steps. The concept of principle it is not interchangeable with the one of *theory* or *hypothesis*.

"We dissect nature along lines laid down by our native languages. The categories and types that we isolate from the world of phenomena we do not find there because they stare every observer in the face; on the contrary, the world is presented in a kaleidoscopic flux of impressions which has to be organized by our minds - and this means largely by the linguistic systems in our minds. We cut nature up, organize it into concepts, and ascribe significances as we do, largely because we are parties to an agreement to organize it in this way - an agreement that holds throughout our speech community and is codified in the patterns of our language. The agreement is, of course, an implicit and unstated one, but its terms are absolutely obligatory; we cannot talk at all except by subscribing to the organization and classification of data which the agreement decrees. [...] We are thus introduced to a *new principle of relativity*, which holds that all observers are not led by the same physical evidence to the same picture of the universe, unless their linguistic backgrounds are similar, or can in some way be calibrated." (Whorf, 1940/2000, pp. 213–14)

According to Whorf, language is not only good to express or reproduce the ideas or concepts that we have already in mind, but it gives form to our thinking, it is the guide of human mental activity in the analysis of sensory impressions and in the construction of synthetic ideas. Nevertheless, we shouldn't treat the principle of relativity as a radical hypothesis for which though is reduced to language and therefore determined by it:

… the tremendous importance of language cannot, in my opinion, be taken to mean necessarily that nothing is back of it of the nature of what has traditionally been called 'mind'. […] language […] is in some sense a superficial embroidery upon deeper processes of consciousness, which are necessary before any communication …" (Whorf, 1941/2000, p. 239)

Indeed, more or less in depth (and Whorf has never been clear enough on this point), according to this approach language is significantly responsible for the shape of our conceptual system. The particular conditions which conduced Whorf to embrace the relativistic point of view are well known.

For some years Whorf devoted himself to the study of the language Hopi, a language spoken by a Native American population in Arizona. According to Whorf, the

Hopi differs from the SAE[108] languages for some important characteristics, which correspond to differences at the conceptual level and, therefore, to a different *weltanschauung*. One of them, probably the most important, stands in the linguistic and conceptual process that Whorf called *objectification*, for which abstract concepts are provided by features which originally belong to concrete objects (e.g. spatial characteristics). It is not hard to see proximity between the Whorfian objectification and the metaphorical process described by Lakoff & Johnson[109] (see cap. 5).

According to Whorf, a clear example is the concept of time. In Italian (as in English), we can use the plural both with *perceptual spatial aggregates* and *metaphorical aggregates*. For example we say "ten men" but we can also say "ten days". Nevertheless, we can easily perceive ten men together, say 'ten men down the street'. On the other hand, we cannot perceive ten days together, as a group:

"We experience only one day, to-day; the other nine (or even all ten) are something conjured up from memory or imagination." (Whorf, 1939, p. 201)

Someone might find a certain Bergsonian eco in these words (see 2.8).

If ten days are considered as a group, it has to be an imaginary group, mentally constructed. Whorf claimed that our language (English, Italian, etc.) confuses two different situations (perceptual and metaphorical aggregates) and provide one grammatical solution for both of them. In Hopi, according to Whorf, plural and cardinal numbers are used only with entities that can form a perceptible spatial aggregate. In the Hopi language there are not imaginary plural, and cyclic repeating events, likely days or the tolls of a bell, are usually coupled with ordinal numbers. According to Whorf:

"Such an expression as 'ten days' is not used. The equivalent statement is an operational one that reaches one day by a suitable count. 'They stayed ten days' becomes 'they stayed until the eleventh day' or 'they left after the tenth day .' 'Ten days is greater than nine days' becomes 'the tenth day is later than the ninth.' Our 'length of time' is not regarded as a length but as a relation between two events in lateness. Instead of our linguistically promoted objectification of that datum of consciousness we call 'time,' the Hopi language has not laid down any pattern that

[108] Standard Average European
[109] And also with the process of 'spatialization' proposed by Julian Jaynes (1976)

would cloak the subjective 'becoming later' that is the essence of time." (Whorf, 1939, p. 201-202)

English does not make a distinction between counting on discrete entities, counting *per se*, or counting non-perceptible units of cyclic events. In this way, according to Whorf, events acquire spatial qualities and can be grouped, divided and put one alongside the other forming a sequence, for example of days, that we can 'see' altogether in a calendar. This process that Whorf called objectification is similar to the metaphorical mapping between space and time suggested by Lakoff & Johnson (1980; 1999), but with a significant difference: according to Whorf the objectification is a cognitive process guided by the structures of language. In other words, a particular vision of the world, in which for example time is conceived as a space, is due to the fact that the speaker grows up in a linguistic community which talk about time in terms of space. Thus, we think this way because we, and the people around us, talk in this way. Who is born in a linguistic community as the Hopi, doesn't think about time in terms of space, or at least, spatializes time in a very different way. Therefore the worldview of a community is relative to the language they speak, and people who speak a different language think in a different way.

On the other hand, according to the classic version of the metaphor theory in cognitive linguistic and embodied congnition, it is the pre-linguistic experience, sensory and culturally mediated, which gives rise to the space-time mapping. And, to the extent that this mapping is based on sensory-motor experience, it should be the same for everybody, universal. The only relativism admitted is a sort of cultural relativism, according to which a particular cultural practice, which becomes a substantial component of our temporal experience (i.e. calendars, clocks, orthography), can shape our representations in a way that is culture-dependent.

According to Whorf, the spatialization of abstract concepts it is not limited to time, which is part of a global schema of objectification. In SAE languages others abstract entities or qualities such as intensity and tendency are expressed in spatial terms (e.g. we express intensity using adjectives like 'high' and 'low'; tendency using verbs like 'increase' and 'decrease'). Moreover, according to Whorf, this global schema of objectification has a role even in giving form to a theory of knowledge and mind/soul:

> Now when we think of a certain actual rose-bush, we do not suppose that our thought goes to that actual bush, and engages with it, like a search-light turned upon it. What then do we suppose our consciousness is dealing with when we are thinking of that rose-bush? Probably we think it is dealing with a 'mental image' which is not the rose-bush but a mental surrogate of it. But why should it be natural to think that our thought deals with a surrogate and not with the real rose-bush? Quite possibly because we are dimly aware that we carry about with us a whole imaginary space, full of mental surrogates. To us, mental surrogates are old familiar fare. Along with the images of imaginary space, which we perhaps secretly know to be imaginary only, we tuck the thought-of actually existing rose-bush, which may be quite another story, perhaps just because we have that very convenient place for it. The Hopi thought-world has no imaginary space. (Whorf, 1939, p. 208)

It is easy to remain fascinated by the possibility that a mental organization so different from our own could exist. So different that would be immune to the 'doubling mistake' of the ingenuous realism (Ceccato, 1972), which wants the products of perception to be doubled, a copy there, in the real world, and a copy here, in our mind. Two realities, the internal one and the external one, as different as familiar, which is very difficult to think about as a product of a bunch of metaphors.

Even if fascinating, it is really hard to rely on these data. The scientific production of Benjamin Whorf has a remarkable importance in historical terms, and could be consider as a good start-point at a theoretical level, but it cannot provide sound empirical data. For different reasons. Nobody knows, for sure, if Whorf has obtained information about the Hopi language directly from native speaker informers or studying linguistic material collected by others (Casasanto, 2008). Moreover, the anthropologist and linguist Ekkar Malotki published in 1983, after many years of research, a volume called Hopi Time in which he provided hundreds of linguistic examples to prove that most of the Whorfian theories about Hopi language were wrong. Although this work, also, has been subjected to some critics,[110] it clearly suggests that many of the Whorfian claims have to be put in perspective and, among a scientific community that was already

[110] According to Lucy (1996), Malotki's critic against Whorf has managed to miss completely the point about grammatical structuration, which is fundamental for the validity of Whorfian arguments.

skeptic about linguistic relativity, it has largely contributed to a general refusal of Whorfian hypothesis.

However, even if all these criticisms will reveal themselves to be groundless, there would still be one major limit, namely the fact that Whorf conclusions are based mostly on linguistic data only and, as noted by Daniel Casasanto (Casasanto, 2008), reasoning that cognitive differences among speakers of different languages can be inferred solely from linguistic differences, often assume the form of a hopelessly tautology:

A: Hopi Indians speak in a different way, therefore they think in a different way.
B: How do you know that they think in a different way?
A: Well, because they speak in a different way!

As suggested by Casasanto:

> "Patterns in language can serve as a source of hypotheses about cognitive differences between members of different language communities, but some sort of extralinguistic data are needed to test these hypotheses: Otherwise, the only evidence that people who talk differently also think differently is that they talk differently!" (Casasanto, 2008, p. 67)

## 11.2 The Whorfian effects. Cross-linguistic differences in temporal thought.

In the last fifteen years we assisted to a reevaluation of the principle of linguistic relativism by the community of cognitive science. Although we are far from a general hypothesis about the relationship between language and thought, many convincing evidences regarding the influence of specific linguistic structures on cognitive processes has become available thanks to recent cutting edge studies. These documented effects of language on thought are usually called "Worfian effects" (Casasanto, 2008b, Bottini & Kuirsten, in press), and most of the time they are based on extralinguistic data in order to avoid any tautological conclusion.

Whorfian effects have been found at many levels of cognitive processing (See Boroditsky, 2003 and Bottini & Kuijrsten, in press for a review): color perception and categorization (e.g. Roberson, Davies, Davidoff, 2000; Winawer et al., 2007), spatial orientation and judgments (e.g. Levinson, 2003), categorization and judgments of substance/form (e.g. Lucy, Gaskins, 2001) and grammatical gender (e.g. Boroditsky, Schmidt, Phillips, 2003), numerical judgments (e.g. Gordon, 2004; Gelman, Gallistel, 2004 ), and others. Here we are going to focus on the Whorfian effects in regard of temporal reasoning and conceptualization.

Does people who speak differently about time conceptualize it in a different way? In other words, can the use of particular metaphorical expressions shape our conceptual metaphors of time independently to sensory-motor experience and cultural influences? Till what extent?

As we have already seen, in English (as in Italian and many other languages) we describe the flow of time, and the succession of events according to a front/back spatial polarity along a horizontal line. In Mandarin, although the front/back metaphor is common (Scott, 1989; Boroditsky, 2001, 2007), time is also expressed in terms of up and down. The locative morphemes *shàng* (up) and *xià* (down) are often used to talk about the order of events, weeks, months, days etc. (Boroditski, 2001, 2007). In Mandarin language, temporal events are disposed along a vertical axis where events that happens before are 'up' (shàng) and the events that happen later are 'down' (xià). Here some example of the spatial and temporal use of the morpheme *shàng* and *xià* in Mandarin:

Space: mao *shàng* shù
cats *climb* trees
Time: *shàng* ge yuè
*last* (or previous) month

Space: ta *xià* le shan méi you
has she *descended* the mountain or not?
Time: *xià* ge yuè

*next* (or following) month[111]

Lera Boroditsky conducted some studies to understand if these linguistic differences in the spatialization of time correspond to cognitive differences in temporal reasoning. In one of her experiments, Mandarin speakers were faster in judging if temporal sentences were true or false (i.e. March is before April) if they were primed with an image of object disposed along a vertical axis, and slower if the prime was an image of objects disposed along a horizontal axis. For English speakers it was the opposite. Moreover, the strength of the vertical primes effect in bilingual (Mandarin-English) subjects varied proportionally to age at which subject started learning English: for subjects who had learnt English when they were very small, the effect of vertical prime was reduced or even absent. In a subsequent experiment, Boroditsky trained a new group of English speakers to use Mandarin-like vertical spatial metaphors for time.[112] After brief training, English speakers showed a pattern of priming similar to native Mandarin speakers. The author concluded:

> "Language can be a powerful tool for shaping abstract thought. When sensory information is scarce or inconclusive (as with the direction of motion of time), languages may play the most important role in shaping how their speakers think." (Boroditsky, 2001, p. 20)

In another recent study (Casasanto et al. 2004; Casasanto, 2008b) two languages that can be considered relatively similar, English and Greek, have been compared. This study is of particular interest because it concerns the temporal aspects of duration and it employs a methodology that doesn't require the use of language in order to make the duration judgment required by the tasks. In English, we can talk about duration using spatial metaphors in one or three dimensions. We can use 'distance' (one-dimensional) metaphors like "It has been a long vacancy"; or 'volume' (three-dimensional) metaphors like "To get a visa it usually takes a *large amount* of time". In English, "distance metaphors" are much more frequent than "amount metaphors" to talk about time; in Greek it is the opposite. For example, the English expression "a long meeting" (distance metaphor) is naturally translated in Greek as "συνάντηση που διήρκεσε πολύ"

[111] Examples from Boroditsky, 2001
[112] E.g. "Monday is abo ve Tuesday" o "Monday is higher than Tuesday"

(synantisi pou dierkese poli, tr. “a meeting that lasts much”) using an “amount” metaphor (see Casasanto et. al. 2010, Casasanto, 2008b; Casasanto, et al., 2004). Does this difference in language can influence the way a Greek and an English speaker think about time?

To find out, Daniel Casasanto and Colleagues asked to Greek and English speakers to perform a task similar to the “growing lines” task (Casasanto & Boroditsky, 2008) that we have considered in the previous chapters (see for example Chapter 7). Participants saw either lines growing, or tanks getting partially filled, on a computer screen, one after the other. In both cases participants have to estimate how long the ‘growing line’ or the ‘filling tank’ stand on the screen before disappearing. Lines had different duration and spatial length, and tanks had different duration and amount of ‘water’ inside. As in previous experiments (Casasanto & Boroditsky, 2008) English speakers were influenced by the spatial displacement of the line in making duration judgments, so that lines which were longer in space were estimated to be longer in time (even if the average duration for each level of displacement was the same); on the other hand, English-speakers were far less influenced by the relative amount of water in the tanks making duration judgments. Testing Greek speakers, the pattern was exactly the opposite: duration judgments were strongly influenced by the irrelevant amount of water in the tank (more water = more duration), but scarcely influenced by the spatial displacement of the line.

To sum-up, participants not only were unable to ignore the spatial dimension (irrelevant for the trial) when they were making temporal judgments, but this inter-domain modulation took place according to the metaphorical patterns which were more frequent in their mother tongue. These results suggest that differences in the use of metaphors between languages lead English- and Greek- speakers to think about time differently, even when they are not using language. Moreover, as in Lera Boroditsky’s experiment, English subjects trained to speak about time using “amount” metaphors instead of “distance” metaphors,[113] and successively tested, provided results that were statistically indistinguishable from the results of their Greek colleagues.

[113] Participants were trained either using distance metaphors for duration, as they usually do, or using amount metaphors, as it is usual for the Greek speakers. They completed 192 fill-in-the-blank sentences using the words ‘longer’ or ‘shorter’ for distance training and the words ‘more’ or ‘less’ for the amount training. Half of the sentences compared the length or capacity of

According to Daniel Casasanto:

"people who talk differently about time also think about it differently, in ways that correspond to the preferred metaphors in their native languages. Language not only reflects the structure of our temporal representations, but it can also shape those representations. Beyond influencing how people think when they are required to speak or understand language, language can also shape our basic, nonlinguistic perceptuomotor representations of time." (Casasanto 2008b, p. 75)

Moreover, we could see how a short exposure to metaphorical mapping common in Chinese or Greek, but not in English, can make English speakers behave like their Mandarin or Greek colleagues in task of temporal reasoning, even when simple duration estimation are asked, and language is not required to fulfill the test. These so-called training experiments are important for at least three reasons:

1) This finding confirms that the effect observed in the cross-linguistic studies is driven by differences in language and not by other cultural differences (which is possible if the study provide just correlational data that don't imply necessarily a causal relationship).
2) The methodology used in the training experiment consents to transform a *quasi-experiment* in an *experiment*. In a *quasi-experiment* subjects are not randomly assigned to different groups or conditions, but grouped according to a characteristic that they already possess (i.e. a subject cannot be randomly assigned between the group of 'Mandarine speakers' and 'English speakers', as it is impossible to randomly assigned a subject between the group of 'men' and 'women'). The disadvantage of quasi-experiments is that they are more open to confounding-variables, which cannot be controlled by the experimenter. For example, concerning the Greek/English crosslinguistic experiment, the effect could be driven by other cultural differences between the two populations: from

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physical objects (e.g., An alley is longer/shorter than a clothesline; A teaspoon is more/less than an ocean) and the other half compared the duration of events (e.g., A sneeze is longer/shorter than a vacation; A sneeze is more/less than a vacation). (Casasanto, 2008b) the pace of life (Levine, 1999) to the different consume of olive oil.[114] In a training experiment the incidence of these confounding-variables is drastically reduced, and participants are randomly assigned to one of the two training conditions (i.e. "distance metaphor training" or "amount metaphor training").

3) These results, once again speak for the flexibility of our conceptual system and its metaphorical structure.

Back to the principle of linguistic relativity, the study reviewed above has shown how the habitual use of different metaphors for time in different natural languages influence the way people reason about time up to nonlinguistic perceptuomotor representations of duration. However, even if English, Greek or Mandarin speakers use different spatial metaphors to talk about time, they all use spatial metaphors. The use of spatial metaphors to talk about time seems to be widespread across languages (Haspelmath, 1997) supporting the proposed universality of such a metaphorical conceptual mapping (Lakoff & Johnson, 1999). As Fauconnier and Turner pointed out: "Time as Space is a deep metaphor for all human beings. It is common across cultures, psychologically real, productive and profoundly entrenched in thought and language." (2008, p. 55) Indeed, as the classic formulation of metaphor theory has suggested (See chapter 5), we learn to conceptualize time in terms of space on the basis of sensorimotor experiences that are the same for each human beings in all the corners of the world, from an African desert to the New York City:

"Why we do have such metaphors for time? Why should the same ones occur in very different languages around the world? The answer is that these metaphors 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 …" (Lakoff & Johnson, 1999, p. 151)

A similar point of view is explored by Casasanto in the case of duration experience:

[114] A significant gastronomical difference remarked by Daniel Casasanto helping me to understand the difference between an experiment and a quasi-experiment (personal conversation).

It is not plausible that using temporal metaphors in language creates the capacity to estimate brief durations, because prelinguistic infants and non-human animals share this capacity. Consider, instead, that some mappings from concrete to abstract domains of knowledge (such as mappings from space to time) may be initially established prelinguistically, based on interactions with the physical world (Clark, 1973). As an example, people are likely to track the kinds of correlations in experience that are important for perceiving and acting on their environment; they learn to associate time with linear space by observing that more time passes as moving objects travel farther, and likewise they learn to associate time with amounts of substances accumulating in three-dimensional space by observing that more time passes as substances accumulate more. This proposal presupposes that although mature time representations depend in part on spatial representations, time can also be mentally represented qua time, at least initially: In order for cross-dimensional associations to form, some primitive representations must already exist in each dimension. Primitive temporal notions, however, of the sort that we share with infants and nonhuman animals may be too vague or fleeting to support higher order reasoning about time. Grafting primitive temporal representations onto spatial representations may make time more amenable to verbal or imagistic coding and may also import the inferential structure of spatial relations into the domain of time (Pinker, 1997), facilitating the comparison of temporal intervals, transitive inference, serial ordering, and other such mental operations that humans have evolved to perform in the domain of space. (Casasanto, 2008b, p. 73)

In this view, the role of language is limited to a modulation of a pre-existant, pre-linguistic and experience-based conceptual mapping which can lead to relatively different spatializations of time. Referring to the Whorfian effects found across English and Greek speakers Casasanto suggest:

Later, as children acquire language, these mappings are adjusted: Each time we use a linguistic metaphor, we activate the corresponding conceptual mapping. Speakers of “distance languages” like English then activate the time-distance mapping frequently, eventually strengthening it at the expense of the time-amount mapping (and vice versa for speakers of “amount languages” like Greek). At a neural level, long-term strengthening of the more frequent association at the expense of the less frequent association could be mediated by competitive Hebbian learning, and short-term adjustments in the strength of these mappings (due to immediate physical or linguistic experience) could be mediated by more transient neuromodulatory processes. (Casasanto, 2008b, p. 74)

This theoretical view has two important implications:

1) it doesn't matter how much languages can differ, all its speaker should show a basic space-time mapping.
2) Even if a language does not use spatial metaphors to talk about time, speakers of that language should think about time in terms of space on the basis of a pre-linguistic, universal conceptual mapping.

Both these claims can be tested empirically. The ideal testbed would consist in a community of people whose language does not use spatial metaphors to talk about time. Such a linguistic community has recently been found.

## 11.3 Time and space in Amondawa culture and language

Recently, Chris Sinha and colleagues (Sinha, Sinha, Zinken & Sampaio, *in press*. From now, 'SSZS') has drawn the attention of linguists and cognitive scientist over a small community of people who leave in a quite isolated area of the rain forest in Brazil. It is the community of the Amondawa. Sinha and colleagues have challenged the hypothesis of the linguistic universality of the space-time mapping (Haspelmath, 1997) on the basis of the data collected on the language spoken by this community:

"Linguistic space-time mapping at the constructional level is not a feature of the Amondawa language, and is not employed by Amondawa speakers (when speaking Amondawa). Amondawa does not recruit its extensive inventory of terms and constructions for spatial motion and location to express temporal relations." (Sinha et al., *in press,* from the abstract)

Indeed, a language which these characteristics could be an important test-bed for the hypothesis about the universality of the basic space-time mapping at the conceptual level, which should be present independently of the presence of spatial metaphors for time in natural language (See previous chapter, especially 11.2).

In this chapter we'll offer an overview on Amondawa culture and language, focusing on the findings that provide evidences for the lack of spatial metaphors for time. Finally, we will provide original data (although preliminary) about Amondawa expression of duration, an aspect of language that hasn't been considered extensively in former investigations (Sinha et al., in press; Sampaio et al., 2009; Sampaio, 1996).

### 11.3.1 Introduction to the Amondawa culture and language

The Amondawa are an indigenous group living in the Uru-eu-wau-wau reservation, in the State of Rondônia in Brazilian Greater Amazonia. Amondawa is a Tupi Kawahib language, closely related to the other Kawahib languages (Diahoi, Karipuna, Parintintin, Tenharim, Uru-eu-uau-uau) of Amazonian Brazil, which belong to the family Tupi-Guarani (Sampaio, 1996; Sampaio and Silva, 1998).

The current population is about 130 people, and the first official contact with non-indigenous people was established in 1986 by the government agency FUNAI.[115] After the first contact, the population was drastically reduced (principally because of contact-induced disease; e.g. tuberculosis, colds, chicken pox) from 160 individuals to no more than 45 people in 1991 (Simha et al., in press). At present, the population is skewed towards the younger generation which makes up more than a half of the population.

The political organization is characterized by two forms of authority. One, represented by the person of the Chief or Cacique, is traditional, transmitted to descendents and retained until death. The second authority is usually a younger man, democratically elected by the whole community to be president of the Indigenous Association. The Indigenous Association is a creation of the Federal Government intended to facilitate the direct allocation of resources to the community. The president of the association has a substantial political power and he's usually in charge to represent the community in the relationships with the Municipal Council, State and Federal Government Agencies. However, most of the decisions about political issues

[115] Fundaçao Nacional do Indio.

are taken by the president only after previous consultation with the Cacique and the community.

The Amondawa kinship system, in common with other Tupi Kawahib groups, is organized in terms of exogamous moieties. Descent is patrilineal. The woman does not lose her paternally derived name when she marries, but her children will be the descendent of her husband and adopt names from his moiety (Sinha et al., in press). The Amondawa moieties are designated by the bird names Mutum and Arara.[116]

The productive activities of the community are mostly based on cultivation of corn, beans, rice, potatoes and manioc. The largest part of the harvest is used directly for the subsistence of the community, but a part of it, especially manioc flour, is destined to the market. The money earned by this trade is usually used for buying manufactured products, such as soap, clothes, shoes, TV‘s. Hunting and fishing, traditionally significant activities, remain the other main sources of food.

Traditionally, education was provided orally and informally by the older member of the community, but since 1994 a school has been provided by the state. School teacher are Amondawa who have been preventively formed by Brazilian volunteers. Lessons are taught both in Amondawa and Portuguese. Portuguese language has a high status in the community because allow its member to communicate with Brazilian people outside the village. Today the majority of the Amondawa people are bilingual and children start to learn Portuguese when they are very young. Most of the communication between the member of the community (especially when elderly people are included) is still in Amondawa, but the tendency among the young members is to prefer Portuguese also for internal communication. The risk that in the space of few generations there will be no more Amondawa speakers is therefore high.

The community Amondawa has cosmological myths about the creation of the natural world, as the separation between the heart and the sky, or the creation of the moon. Other traditional stories talk about legendary animals and men who were living in the village or in the forest. Wany Sampaio and Vera da Sliva Sinha have collected some of these narratives in their book “Mitos Amondawa” (2004).

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[116] The *mutum* is a black bird living almost all the time on the ground and the *arara* is a colourful macaw that lives in the highest trees.

### 11.3.2 Space and time in Amondawa

Amondawa time

An abstract term for *time* does not exist in Amondawa. According to SSZS, the term *kuara*, that has the original meaning of ‘sun’, is used in some cases to denote temporal intervals in general, probably because the movement of the sun governs ‘natural’ temporal intervals such as the ‘time of the day’ or the seasons.[117]

There are in Amondawa no words for weeks, months and years. Though, there are names for seasons and parts of the seasons, for the day and night and parts of the day and night, and some temporal deictic and adverbial terms. SSZS failed to find any term for time-referenced festivals such as our Christmas or Easter, and it seems that such a recurrences do not exists in the contemporary Amondawa culture.

Linguistically, time in Amondawa is divided not into years, but into two seasons: the dry season *Kuaripe* (‘in the sun’) and the rainy season *Amana* (‘rain’). The term Kuaripe, referring to the hot, dry season, derives from the noun *Kuara* (‘sun’), with the locative postposition *pe*, meaning ‘in’ or ‘at’. The rainy season is designated simply by the noun for ‘rain’. Each season is further subdivided into three intervals as shown in table 2.

| **Amondawa** | **English** |
|---|---|
| ***Kuaripe*** | **Time of the sun (“SUMMER”)** |
| *O´an kuara* | “The sun is born”. The arrival of the sun (beginning of the time of the sun). |
| *Itywyrahim kuara* | “Burning sun”. Very strong, hot sun, high summer. |
| *Kuara Tuin*<br>*Or*<br>*Akyririn Amana* | “Small sun”. End of the time of the sun.<br>Or<br>“Almost rain”. The time of falling rain is close. |

[117] It is possible that we are facing here to a case of abstraction similar to the one documented by Boroditsky & Gaby (2010) in the community of Pormpuraaw (See cap 10). In that case, the motor trajectory of the sun (from east to west) which can be used to mark successive moments of the day (e.g. morning-noon-evening) is abstracted and (metonymically) used to lay out successions of events at different scales. Here, the duration of a particular event such as the period of day-light could be used metonymically to denote a certain duration in different scales.

| *Amana* | **Rain / Time of the rain (“WINTER”)** |
|---|---|
| *Akyn Amana* | “Falling rain”. The arrival of the rain. |
| *Akyrimba´U Amana*<br>*Or*<br>*Amana Ehãi* | “Heavy falling rain”. Time of the heavy rains.<br>“Great rain”. Rain of long extent and duration. |
| *Amana Tuin*<br>*Or*<br>*Akyririn Kuara* | “Small rain”. End of the rainy season.<br>Or<br>“Almost sun”. The time of the sun is close. |

Table 2. Amondawa seasonal time interval words. (Source, Sinha et al, *in press*)

The term for ‘day’ in Amondawa, *Ara*, has also the meaning ‘sunlight’ and doesn’t refer to the 24-hour day, but only to the daylight hours. The term for night is *Iputunahim*, which also means ‘intense black’. There is a major subdivision of *Ara*, ‘day’, into two parts, *Kóema* (morning), and *Karoete* (noon/afternoon), and both day and night are further subdivided into intervals which are named on the basis of particular daily activities, as shown in table 3.

| ***Ara or ajia*** | **Day (daylight)** |
|---|---|
| ***Ko´Ema*** | **Morning** |
| *Pojiwete* | “When we start work”. Early morning. |
| *Kojawahim* | “When we feel hungry”. |
| *A´U Matera* | “When we eat”. Lunchtime. |
| *Ajia Katua*<br>*Ajimbu´U* | “Good morning time”. After lunch.<br>“Heavy morning” Late morning. |
| *Pyriete Kuara Ruwi Ajia katua* | “The sun is high” High noon. |
| ***Karoete*** | **Noon; afternoon**. |
| *Pyryrym Kuara* | “The sun is turning”. Early afternoon. |
| *Momina Werin Kuara* | “The sun is almost gone”. Late afternoon, dusk. |
| *Momina Kuara* | “The sun is gone”. Early evening. |

| | |
|---|---|
| | Twilight. |
| *Iputuna* | **Night (black)** |
| *Opon Jahya Tiro* | "The moon leaps up now". Moonrise. |
| *Apehyiahim* | "No more work intense". Sleep time. |
| *Apoji Katua*<br>*Ypytunahim* | "Good .... "<br>"Intense darkness" Middle of the night. |
| *Pyriete Jahya Ruwi* | "The moon is high in the sky". |
| *Jahya Pyryrym* | "The moon is turning". Dawn is coming. |
| *Ko΄Ema Werin* | "Almost morning". Dawn. |
| *Opon KuaraTiro* | "The sun jumps up now". Sunrise. |
| ***Ko΄ema*** | **Morning** |

Table 3. Parts of the day in Amondawa (Source, Sinha et al, *in press*)

The numerical system in Amondawa doesn't go above four,[118] therefore, the age of an individual is not measured chronologically. In the Amondawa culture individuals are categorized according to the status occupied in family and society. Each individual change his name when he goes from a life stage to another in the course of his life, and his approximate age can be inferred by his name. In each case, and for each level, there is a finite number of name (each of which has a semantic value indicating moiety, gender and life stage), which form a strict onomastic system (Sinha et al., in press). For example, when a new child born in a family, he will assume a 'newborn' name, which could be also the name previously held by his youngest brother. Moreover, regardless of the name given to the newborn, all the existing children will acquire a new name.

An individual change his name when he left the childhood for the adult age. When the older child of a family changes his name, the father changes his name too. The assumption of a grown-up name coincides with the assumption of new responsibilities for this member of the family.

[118] The Amondawa number system has only four numeral terms. The two basic numbers are *pe'i,* 'one' and *monkõi*, 'two'. The equivalent of the English 'three' has two different lexicalizations *monkõiape'i* or *ape'imonkõi*, as well as 'four', *monkõiuturaipei* and *monkõimeme*. (Sinha et al., *in press*)

Other more general aged-based categories has been indentified:

| | |
|---|---|
| Kurumin | Baby/child |
| Kwambàea<br>Kuñã | Man<br>Woman |
| Amu<br>Tiwi | Old man<br>Old Woman |

Table 3. Generic nouns referring to categories of persons (Source, Sinha et al. in press)

According to SSZS:

"Amondawa has […] a nominal suffix system, in which the termination of relations to things or states in the past, or the expectation of them in the future, is marked on the noun (analogously to expressions in English such as ‗ex-husband‘ or ‗husband-to-be‘)." (Sinha et al., in press, p. 31)

In amondawa it is not obligatory to specify event time, and in most cases temporal reference is interpreted according to the context (Sinha et al., in press).

When temporal specifics are required, past of future is marked by temporal deictic adverbial particles and dependent morphemes:

Future: *-nehe, poti, poti...nehe*

Past: *ki...ko, ki...i΄i, emo, ramo*

Present (or immediate furure): *tiro, koro*

SSZS provides the following example:

(16) *T-aho* *koro ´i* *ga* *nehe*.

REL-3SG.go now.INTENS he FUT ‗

'He will go out (from here) just now.‘

(Proximal Future)

(17) *Kuaripe* *taian ´i* *ga* *nehe*.

dry season arrive.INTENS he FUT

'He will arrive in the summer (dry season).'

(Distal Future; spoken during rainy season)

(18) *Da-o-ur-i* *ki* *ga* *ko*.

NEG-3SG-come-NEG PAST he PAST

'He did not come.'

(Past)

Space-time mapping in Amondawa

We could see that Amondawa language possess a discrete temporal lexicon and the grammatical resources to indicate the past, present or future occurrence of an event. Do, spatial lexical items (such as locative morphemes or motion words) are used in Amondawa for temporal expression as in many other languages? SSZS gave a negative answer.

According to them, even if Amondawa possesses a diverse lexical and constructional repertoire for the conceptualization and expression of location and spatial motion,[119] and there are no lexical restriction rules or other intra-linguistic constraints

[119] *Motions verb*:

| | |
|---|---|
| *-ho* | go, exit (basic motion verb) |
| *-hem* | exit |
| *-xi* | enter |
| *-jupin* | ascend, climb |
| *-jym* | descend |

*Propositions*:

| | |
|---|---|
| *pe* | at, to, in |
| *pupe* / *pype* | in, inside, into, to the inside |
| *wi* | from, out of |
| *re* | up, up in, up on, up into, up onto |
| *katy* | nearby (stative) |
| *aramo* | over, above |
| *urumõ* / *urymõ* | under, below, beneath |

that preclude the use of words with motion and location meanings for temporal expressions, no case of temporal use of spatial expressions has been found (Sinha et al., *in press*).

SSZS observation wasn't based only by spontaneous and elicited speech data, but they also used structured questionnaire items (Zinken et al., 2005) to ask bilingual Amondawa speakers to translate Portuguese temporal expressions like this:

-O ano que vêm. (The coming year)

in which locative and motion words are used metaphorically to talk about temporal events.

According to SSZS, in all cases the speakers rejected the possibility to use Amondawa motion verbs in 'Time-moving' and 'Ego-moving' temporal constructions (See chap. 5).

Moreover, SSZS asked Amondawa speakers to narrate the well-known Frog Story (Berman & Slobin, 1994) and they failed to find any positional temporal adverbs corresponding to the English 'before' and 'after'.

In short, according to SSZS, Amondawa provide negative evidences for the universality of the space-time metaphorical mapping in language (Haspelmath, 1997). Nevertheless SSZS have focused their study on the constructional expression of relational temporal notions, in which an event is situated in relation to an implicit or explicit temporal reference point. Simpler lexical space-time mappings in duration terms (e.g. Eng. long) have not been systematically investigated.

## 11.4 The mediated mapping hypothesis

SSZS reject the radical interpretation often associated with the Hopi indians (Pinker, 1994), according to which Amondawa are "people without time". As we have seen, Amondawa language has a nominal aspect system and temporal deixis which

| | |
|---|---|
| *pywõ* | by, _past (path, dynamic) |
| *rupi* | along (a path) |

(source: Siha et al., in press)

allows to distinguish, at the linguistic level, past and future events. They have cultural narratives of the collective past and mythic narratives, they mark the passage from a life stage into another, and they are able to linguistically conceptualize inter-event relationships (Sinha et al. *in press*). Indeed, the absence of a term to denote what we call 'time' should not prevent Amondawa people to understand and talk about temporal relations, as well as the absence of an abstract term for 'cause' shouldn't prevent to grasp and describe basic relation of causality. Since we want to understand how basic temporal relations are encoded in language, and if the specific grammatical structures employed can shape temporal reasoning differently from language to language, it is important to study the metaphorical structuring of temporal language regardless of the limitation of the specific temporal lexicon. The total lack of spatial metaphor for time in a particular language, if only for its rarity, needs an explanation and might also coincide with a more or less peculiar and cultural idiosyncratic way to represent time and temporal relation at the non-linguistic, cognitive level. Although, we have seen how time is not a cognitive monolith but rather has many, related, conceptual and linguistic aspects such as succession, duration, direction, extension, etc. A complete linguistic overview on the domain of time has to consider systematically all of these aspects. Before focusing on the expression of duration in Amondawa, we will review the theoretical proposal provided by SSZS to account both for the ubiquity of space-time mappings and for their absence in some languages.

SSZS provide a theoretical proposal that they call "The mediated mapping hypothesis". According to these scholars:

> "Contrary to the assumptions of many cognitive scientists, we maintain that there is no natural, prelinguistic and preconceptual schema of Time that, as it were, passively invites and receives (by way of image-schematic structural correspondence) mappings from spatial relational concepts, words and constructions" (Sinha et al., in press)

If we have understood the hypothesis well enough, according to SSZS there is not a prelinguistic conceptual domain of time, based on sensory-motor experience, or event perception, which can receive the mapping from the spatial conceptual domain. Rather, such a concept of time has to be constructed, and it is a historical construction, based on social practices and cultural products. SSZS call this basic temporal domain

‘Time as such’, and it goes without saying that, because of his historical and cultural origin, it is not universal *a priori*. According to SSZS:

> “Our usual cultural presupposition is that time, […], constitutes a domain of thought-about, reflective experience, schematized in linear or cyclic terms, that is in some sense independent of the events that occur in time. This abstract conceptual domain we shall refer to as Time as Such” (ibid. p. 6)

The notion of *Time as such* is similar to the Newtonian absolute time, or in psychological terms, to the Kantian time as a pure form of intuition (See 2.5 and 2.7). In both cases time can be seen as a homogeneous medium, and as a necessary condition for the existence of the reality (Newton), or the possibility of knowledge (Kant), which can be considered independently of the events that happens *in* time. SSZS remark the cultural relativity of the notion of Time and Such, suggesting that even certain aspects of the concept of time, which are usually considered universal because reflect characteristics of the physical time (See chapter 1), of the events themselves (Boroditsky, 2000; Lakoff & Johnson, 1999), are instead to be considered as culturally achieved, and therefore potentially absent in some culture. For example, in the representational frame of time as such, time can be arbitrary divided in temporal intervals (e.g. weeks, month, minutes) whose duration is fixed and independent of the events that take place in time. It is a time completely detached from its content, empty as the Kantian time, or ‘without quality’ as suggested by Bergson (1889/1910). SSZS call this representation of temporal intervals the *Time-based time intervals system*, and opposes it to the *Event-based time interval system*. In the second case, the boundaries of the temporal intervals are constituted by the events themselves, such as sunrise or a particular activity like ‘lunch’. In this sense, there is no cognitive differentiation between the time interval and the duration of the event or activity that defines it. According to SSZS, Amondawa time is based on such a Event-based system, in which, for example, the subdivision of day and seasons is strictly related to natural events, or work activities.

According to SSZS, the existence of time-based time interval systems enables the framing of events in *Time as Such*, which in turn, they propose, permits the space-time frame mappings. We should remark again that when SSZS talk about the 'space-time frame mapping' they refer explicitly to the "ego-moving" and "time-moving" metaphorical schema,[120] both in language and thought. This mapping, which according to Lakoff and Johnson is based on primary experiences in which 'moving in space' and the experience of the 'passage of time' are conflated together (see 5.2), is rather possible only if there is a cultural constructed schema of time (namely *Time as such*) with certain characteristics, that are not the characteristic of a vague pre-linguistic and sensorial-based experience of the "passing of time".

The 'time-based' time interval system permits the framing of inter-event relationships as dynamic or static relations occurring within a schematic 'time frame' that is conceptually autonomous from the events thus framed. This time frame (namely, *Time as such*) has a direction from the past to the future and a 'now' (so a deictic point of reference) and it is represented as a line or a circle.

In our understanding these are the characteristic of the "passage of time" which should be the target domain of the metaphorical mapping,[121] a passage of time that seems somehow already *spatialized*, and it is the pre-condition and not the result of the metaphorical mapping from space. Indeed, SSZS write:

> "it is the constructed temporal schemas of linearity and cyclicity that permit the conceptualization of temporal relationships as existing in a domain of content that is abstracted from the events themselves. It is this (in some sense imaginary) content that we designate `Time as Such'" (Sinha et al., p. 6)

and,

[120] They also refer to non-deictic positional frame, in which dynamic succession of events is framed in terms of 'before' and 'after' (in front/behind) of other event, without a deictic perspective from the 'now' as happen for the Ego-related (ego moving/time moving) schemas. Think for example to the days in a calendar or a horizontal (non-sagittal) time-line, in which Friday is 'in front' (before) or Tuesday independently of the 'now'. In other words, events are schematized as a sequence of different position on a path, considered independent of the position of the EGO. (See Moore, 2006)

[121] Characteristics which cannot derive directly from the experience of events, but have to be culturally and cognitively constructed.

"even if it is the case that space-time mappings are motivated by compelling inter-domain analogic correlation, and perhaps facilitated by neural structure, it is the cultural, historical and linguistic construction of the domain of 'Time as Such' that potentiates the linguistically widespread (but not universal) recruitment of spatial language for expressing temporal relations in space-time mapping constructions." (ibid. p. 42)

to our understanding, it is *Time as such* the target domain of the metaphorical space-time mapping, and not a generic and universal experience of the 'passing of time', a pre-linguistic, pre-conceptual and sensory-motor temporality. The absence of the Ego- and Time- moving metaphorical constructions in the language Amondawa (and presumably also at the cognitive level), should exclude the case of a mapping based on universal experiences (Lakoff & Johnson, 1980; 1999; Boroditsky, 2000; Casasanto, 2008b).

According to SSZS, therefore, a temporal conceptual domain organized like "Time as such" is necessary in order to receive the spatial mapping necessary for Ego-relative (an positional, also) temporal schema. They also explain which cultural practices are at the base of this temporal cognitive category:

"Our account therefore proposes that analogical, frame-to-frame space-time mappings are the emergent product of the intercalation of numeric symbolic cognitive processes with language, supported by historically developed cognitive artefacts such as calendars and clocks." (Sinha et al. )

Numerical notation is itself a cognitive artefact, which lacks in Amondawa culture and language. The existence of a system with large exact numbers, together with other system of temporal notation are for SSZS <u>necessary</u> in order to built-up the cognitive category of time as such:

"Amongst the symbolic resources necessary for the cultural emergence of time-based time interval systems, such as true calendric and clock systems, is the existence of a more elaborate number system than the restricted Amondawa quantificational system" (ibid. p. 41)

Although necessary, numerical and calendric systems, are not sufficient to the emergence of a time based time interval system.

In summary, according to SSZS, the cognitive and linguistic domain of 'Time as Such' is not a cognitive universal, "but a historical construction based in social practice, semiotically mediated by symbolic and cultural-cognitive artefacts for time based time interval reckoning, and subsequently entrenched in lexico-grammar." And "Linguistic space-time mapping, and the recruitment of spatial language for structuring temporal relations, is consequent on the cultural construction of this cognitive and linguistic domain." (ibid., p. 43).

Time-based time interval systems and the metaphorical schemas that are built up on it, are in a fundamental way "linguistically constructed", in the sense that 'they cannot be thought without thinking them through language and for speaking" (Ibid. p. 41), because "The conceptual schematization of time-based time interval systems is not based in pre-linguistic and pre-conceptual image schemas" as, for example, Lakoff & Johnson might think (Lakoff & Johnson, 1999; and cap. 5.2), rather, "conceptual schemas such as the calendar are constituted by the use of linguistically organized, materially-anchored symbolic cognitive artefacts". Whorf talking about the Hopi Indians, has written that they: "has no general notion or intuition of time as a smooth flowing continuum in which everything in the universe proceeds at an equal rate, out of a future, through a present, into a past; or, in which, to reverse the picture, the observer is being carried in the stream of duration continuously away from a past and into a future." (Whorf, 1950 p. 27). A similar thing can be said for the Amondawa language and culture (Sinha et al. *in press*). The authors precise that, the absence of such patterns in language (i.e. ego-/time- moving metaphors) doesn't imply the absence of universal cognitive capacities. SSZS, provide instead evidences that, when induced, and taught, to think and talk about time according to a ego-related moving schema, Amondawa speakers can do that without too much effort,[122] even if they usually don't do that, even

[122] In this experiment (Sinha et al., in press, Task 4), the experimenter manipulated in front of the observer paper capsules that were designated and named as Amondawa temporal intervals (e.g. 'dry season'; 'wet season'). During the experiment, the experimenter laterally moved one of the figures along the imaginary line so that it reversed its relative position in

if they, according to SSZS, do not think that way. In other words, the cognitive category of Time as such, and consequentely also the ego-related (and positional) time-moving metaphorical schemas, are present 'in posse' in all human beings, but its employment, 'in esse', depends on cultural, social and linguistics practices.

## 11.5 How Amondawa talk about duration?

The linguistic investigation o SSZS was focused on temporal metaphors of movement in space, like the ego-relative schemas. They indeed failed to find such metaphorical expression in Amondawa. Nevertheless, they did not systematically investigate another important, and usually spatialized (both in language and though, see part II of this thesis), aspect of temporal experience: the experience of duration. How Amondawa speakers talk about duration? Do they use spatial metaphors like in English (e.g. a *long/extended/protracted/lengthy* vacation)? And, more specifically, does the metaphorical mapping responsible for the spatialization of temporal extensions (duration) is possible only on the basis of a cognitive frame as the Time as such?

We present here a preliminary linguistic investigation on the duration terms in Amondawa. The data we have collected come from a single interview with two members of the community Amondawa. This interview represents the first step of a project of research on Amondawa Language and though which I'm conducting in

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relation to the other figure or to a doll (ego-doll) representing an observer situated on an imaginary line of movement. Basically, a time-moving schema was simulated, with the capsules temporal intervals that moved toward or away from the observer. The participant was simply asked (in Portuguese) to describe in Amondawa what they had seen.
Participants produced phrases like these:

*O-ho kuara tiro.*
3SG-go sun now =
The sun/dry season goes.'

*Akuam kuara.*
cross sun
'The sun/dry season has passed across'.

According to SSZS the elicited utterances demonstrate that there are no lexical restriction rules or other intra-linguistic constraints in Amondawa that preclude the use of words with motion and location meanings for expressing motion events and Figure-Ground relations involving time interval nouns (Sinha et al. p. 35). Nevertheless, these utterances were elicited in situations involving actual spatial motion (of the paper capsules). And, according to SSZS, it would be an over-interpretation to claim that they instantiate space-time linguistic mapping.

collaboration with Daniel Casasanto, Chris Sinha, Vera Silva Sinha and Wany Sampaio. The questionnaire that we have used to collect these first data has been prepared by Roberto Bottini and Wany Sampaio, and administered by Wany Sampaio.

The aim of the questionnaire was to investigate how Amondawa speak about duration. Here, our primary goal is to understand if Amondawa speakers use the same expression to designate spatial extension (i.e. a *long* rope) and temporal extension (i.e. a *long* song). If they do, as well as speakers in many other languages, it would mean that, at least for duration, spatial lexicon is recruited to talk about time, representing a significant exception for the general absence of spatio-temporal metaphors in Amondawa. However, given the limited number of both informants and observations, these data has to be considered as preliminary.

### 11.5.1 Methods

Participants. Two Amondawa native speakers, fluent in Portuguese, who work as teacher in the school of the village.

Procedure and Materials. The questionnaire contained 49 sentences in Portuguese. Some of the sentences described spatial characteristics (i.e. size, length) of objects and animals or spatial relations: e.g. "a *long* rope"; "a *long* leg"; "a *big* house"; "a *small* monkey"; "I'll wait for you *in the middle* of the forest"; etc. The rest of the sentences described temporal characteristic (i.e. duration) of events or temporal relations between events: e.g. "a long conversation"; "a short song"; "A butterfly has a short life"; "My sister was born after me"; etc.

The sentences were red by the experimenter (W.S.), and the participant could also read each sentence on the paper. The participant was asked to provide a translation in Amondawa, which was written by the experimenter and controlled by the subject.[123] Participants have been told that the questionnaire aimed to investigate spatial and temporal expressions in Amondawa.

[123] Both the subjects were literate.

**11.5.2 Results**

Both participants didn't translate all the sentences, principally because were bored or tired, but also because they did not know how to translate certain Portuguese sentences in Amondawa. As anticipated before, here we are going to focus only on the expressions of duration, compared to spatial expressions of size, and length:

**Length (Spatial 1-dimension)**

*1. Uma perna comprida*

Aetymakãga ipuku

| | | |
|---|---|---|
| Ae | -tymakãg-a | i-puku |
| Poss. hum. | -perna-nom. | poss 3 ñ.hum-comprido |

2. *Uma corda comprida*

inamyiamua ipukuribuhu

| | |
|---|---|
| inamyiamu-a | ipukur-ibuhu |
| corda-nom. | comprido-intens. |

3. *Um cabelo comprido*

jahawa pukuribuhu

| | |
|---|---|
| ji-ahaw-a | pukur-ibuhu |
| pos. hum. 1 s – cabelo - nom. | comprido-intens. |

4. *Um rio comprido*

Yhya pukuribuhu

| | |
|---|---|
| Yhia-a | pukur-ibuhu |
| Água-nom | comprido-intens. |

5. *Uma perna curta*

aetymakãga jaturité

| | |
|---|---|
| ae-tymakãg-a | jatur-ité |
| pos. hum.– perna- nom. | curto/pequeno-intens. |

6. *Uma corda curta*

inamyiamua jaturité

inamyiamu-a    jatur-ité

corda-nom.    curto/pequeno-intens.

7. *Um cabelo curto*

jahawa jaturité

jahawa    jatur-ité

pos. hum. 1 s – cabelo - nom.    curto/pequeno-intens.

8. *Um rio curto*

Yhya jaturité

Yhia-a    jatur -ité

Água-nom    curto/pequeno-intens.

**Size (Space 3-dimension)**

9.*Uma casa pequena*

Tapyia  tuinté

Tapyia    tuin-ité

Casa    pouco/pequeno-intens

10. *Uma casa grande*

Tapyia ehãin

Tapyia    ehãi-in

Casa    grande/muito-intens.

11. *Um macaco grande*

Ka´ia ehãin

Ka´ia    ehãi-in

Macaco    grande/muito-intens.

12. *Um macaco pequeno*

Ka´ia tuinté

| | |
|---|---|
| Ka´ia | tuin-ité |
| Macaco | pouco/pequeno-intens |

**Duration**

13. *Uma longa conversa*

Añyn ipukuribuhu

| | |
|---|---|
| Añyn | ipukur-ibuhu |
| Conversar | comprido-intes. |

14. *Uma cantiga comprida*

| | |
|---|---|
| Aimbuyi | ipuku |
| Cantar | comprido |

15. *Uma longa história*

Materaymana mambeu ipukuribuhu

| | | |
|---|---|---|
| Matera –ymana | mambeu | ipukur-ibuhu |
| Coisa-antigo | contar/narrar | comprido-intes. |

16. *Uma grande conversa*

| | |
|---|---|
| Añyn | ipuku |
| Conversar | comprido |

17. *Uma breve conversa*

Añynga beweibuhu poti nehe

| | | | | |
|---|---|---|---|---|
| Añyn | ga | bewe- | ibuhu | poti nehe |
| Conversar | ele | baixo/achatado- | intens. | Fut. Fut. |

18. *Uma história breve*

Materaymana kotihim

| | | |
|---|---|---|
| Matera | -ymana | kotihim |
| Coisa | -antigo | rápido |

19. *Uma conversa pequena*

Añyn tuinté

| | |
|---|---|
| Añyn | tuin-ité |
| Conversar | pouco/pequeno-intens. |

20. *Precisa de muito tempo para fazer chicha.*

Peweite a ki kawin hea parawakowo

| | | | | |
|---|---|---|---|---|
| Pewe-ite | a ki | kawin | hea | parawako-wo |
| Largo/plano | pass. | chicha | | ela fazer-ger |

21. *Meu avô teve uma vida longa.*

Amui ga pewe akowo

| | | | |
|---|---|---|---|
| Amui | ga | pewe | ako-wo |
| Avô | ele | baixo/achatado | estar vivo-ger. |

22. *A noite de ontem foi muito comprida.*

Pewei waea ki putuna koemame waea

| | | | | | |
|---|---|---|---|---|---|
| Pewei | waea | ki | putuna | koema-me | waea |
| Largo/plano | pass. | pass. | noite | manhã-quando | pass. |

23. *Uma borboleta tem uma vida curta.*

Panama ako tuinte amono

| | | | |
|---|---|---|---|
| Panam-a | ako | tuin-ite | amono |
| Borboleta-nom | estar vivo | pouco/pequeno-intens. | morrer |

### 11.5.3 Discussion

One of the aims of this questionnaire was to test if the lexicon used to design spatial extension (e.g. ‘long rope’; ‘big house’) can be recruited to design the duration of events (temporal extension, e.g. ‘long night’; ‘small song’). Since the informers both agreed claiming that the expressions reported above (1-23) are correct and can be said in Amondawa, at a first look the answer seems to be ‘yes’. The same lexical items used to talk about spatial length and size can be used to talk about duration of events. For example, in (1 – 4) the word *–puku*, is used with the meaning of ‘long’ in space, with different objects (leg; river; hair; rope). Similarly, in (13-16) *–puku* is used with the meaning of ‘long in time’, together with different events like ‘history’ (a long hystory); ‘conversation’ (a long conversation); ‘song’ (a long song). SSZS, reported that when to Amondawa speakers were presented phrases like “o ano que vêm” (‘the coming year’), in all cases the speakers rejected the possibility of using Amondawa motion verbs in Ego-relative temporal motion constructions (Sinha et al., in press, p. 33). Nevertheless, in this case, Amondawa speakers, use spatial terms (long; big) in temporal (duration) construction, claiming that these constructions are correct in spoken Amondawa.[124]

Less straightforward seems the mapping between extension and duration for the other pole of the polarity long/short. In (5-8), the spatial adjective *curto* (short) is used with different objects (leg; river; hair; rope), and it is always given in Amondawa as *-jatur*. Nevertheless, in (23) the temporal meaning of *curto* is given as *–tuin*, which means ‘pouco/pequeno’ (a bit/little-small), a term that it is used in (9) and (12), sentences that describe physical size like “A small house” and “A small monkey”. Moreover, in (18) and (19), the Portuguese ‘breve’ (brief) is given in Amondawa as – *kotihim* (fast) or *-bewe* (low/flat/large). Therefore, the spatial word used for ‘short’ in space (5-8) it is never used to denote short/brief events (in temporal terms). Nevertheless, in (23) short (in time) is given with another spatial term used to denote size and that can be translated as ‘small’; in (18) ‘brief’ is given as – *kotihim*, which can be translated as fast. A term which denote the speed of movement in space, another typical sensory-motor source

[124] Curiously in (16) the 3-dimensional adjective ‘grande’ (big; in “a big conversation”) is translated in Amondawa with *–puku* (long) and not with *–ehai* (a lot/big). This could be explained with a preference, for Amondawa speakers, to talk about duration in 1-dimensional terms (as English). Nevertheless, in (23), the adjective ‘curta’ (short; for “has a short life”) is given in Amondawa with *–tuin*, which means ‘a bit/small’. Here the pattern is reversed, and the original 1-dimensional adjective is translated using a (presumably) 3-dimensional one. Further research should explain these contradiction (if replicated) and clarify if, in any case, we it is always the case of a spatial metaphor (either one- or three- dimensional).

used in many languages to describe short durations (Eng. “a fast conversation”; It. “una conversazione veloce”). The term used in (19), *-bewe*, can be translated as ‘low’/’flat’ and also as ‘large’ but the actual meaning remain ambiguous for us. We will talk more about this special case later. However, according to the data considered until now, we could momentarily conclude that it is present in Amondawa, for the expression of duration, a space-time mapping similar to those we can find in many other languages, as well in English. We want to make clear that neither we are advancing claims about the cognitive, conceptual dependence of time on space (e.g. space-time asymmetry), nor we are presupposing the presence of a conceptual space-time mapping. Our remarks are still limited to the linguistic level.[125]

Nevertheless, a closer look of the data makes possible to advance some doubts about these preliminary conclusions. In (20-23), when it is asked a translation of sentences that draw a more detailed context, spatial lexicon it is usually not recruited for temporal expressions. In fact, with the only exception of (23), in which is used the term *–tuin*, which can be translated as ‘a bit/small’, in the other three cases a spatial term (e.g. *–puku*) is never used to express a long duration. The long duration of the event is rather expressed with *–pewe* (*bewe*, *mbegwe*). *–pewe* assumes here a clear temporal meaning.

In the Parintintin dictionary, the term *-mbegwe* has the temporal meaning of “to take long time” and “be slow”. It is possible that this term is used to denote also the velocity of a movement or a process, but it seems that it cannot be used to denote the length of spatial extensions (‘long rope’, ‘short river’). The same term, with the same meaning exists also in Karipuna, another Khawaib language. Therefore, if *–pewe* (or *-mbegwe*) is a pure temporal term, or a spatial term (i.e. *large*) used in temporal meaning is still an open (and important) question.

In my opinion these results suggest the possibility that the use of the term *–puku* designing temporal durations in (1-4) could be due to a literal translation (maybe word-

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125 The claim that in Amondawa spatial lexicon is recruited to the construction of temporal expressions is indirectly supported, by studies on a related Khawaib language like Parintintin. According to the dictionary of Parintintin by La Vera Betts (1981) *–puku* means ‘long’ both in time and space:
*-puku* /*-mbuku*, *-vuku*/ d: ‘comprido’; ‘por muito tempo’.
*ypuku* s: rio comprido e reto
*-kipuku* vi: dormir muito;

by-word) of generic, decontextualized and unusual sentences. A situation in which the influence of the second language (Portuguese) could be more compelling.

As in Sinha et al. (in press), the results of this questionnaire confirm that there are no lexical restriction rules or other intra-linguistic constraints in Amondawa that preclude the use of words with spatial extension meanings for expressing the duration of events.

In conclusion, more studies are required to understand with more certitude whether or not spatial metaphors are used for duration expressions in Amondawa. In particular, the following doubts have to be addressed:

- Is it possible to use the term *–jatur* ('short') to describe the short duration of an event?
- Do Amondawa speakers usually use the term *–puku* to refer to long durations?
- Is the term *–pewe* (*-mbegwe*; *-bewe*) used just in temporal sentences with the meaning of 'long in time'; 'which take long time'? Has it other non-temporal meanings?

Ideally, different methodology such as questionnaires, structured interview, analysis of spontaneous and elicited speech, should be used. Concerning the questionnaire, translation should be asked both from Portugues to Amondawa, and from Amondawa to Portuguese; and more concrete, specific and contextualized example should be used.

On the basis of future studies we might come to know that Amondawa, and possibly other languages, do not talk about duration in terms of space. This would be, *per sè*, an important discovery, and would definitely falsify the claim of the universality of linguistic space-time mapping (Haspelmath, 1997). Nevertheless we think it wouldn't be enough to sustain that this linguistic differences correspond to cognitive differences between speakers of a different language. Non-linguistic data supporting this hypothesis should be provided as well. Ideally, the combination of linguistic and non-linguistic data should also allow, with a certain degree of confidence, to distinguish the cognitive effects due specifically (or mostly) to linguistic structures and effects due to other cultural variables (e.g. writing direction, but also religious view, social practices, etc.).

# 12. Conclusion.

> "We cannot compare any process with the "passage of time" - there is no such thing - but only with another process (say, with the movement of the chronometer). Hence the description of the temporal sequence of events is only possible if we support ourselves on another process."
>
> Wittgenstein, 1933, par. 6.3611

We concluded the second part of this thesis with some questions:

- How do space and time become asymmetrically linked in our mind?
- In which way time is progressively spatialized through experience?
- Is this process of spatialization equal for every one or could change according to biological and/or cultural constraints? To what extent?

On the basis of the empirical and theoretical data presented on this session we could answer to the third question with some confidence. In chapter 10 we have seen that the spatialization of time is culture-specifics, at least in some important aspects. For example, we have seen that time is represented as flowing from left to right in the mind of Dutch and English people, and from left to right in the mind of Moroccan or Ebrew people. This lateral, culture-specific conceptual mapping is automatically activated during co-speech gestures (Casasanto & Jasmin, 2010), when subject are asked to think about the past or the future in a psychology lab (Ouellet et al. 2010;), and it is explicitly encoded in graphic representation of temporal sequence from the age of 5 (Tversky et al. 1991). Moreover we have provided the first evidence that the direction of orthography play a causal role in determining (or at least consolidating) the orientation of the conceptual time/line. We know, now, that even a short exposure to a new, reversed orthography can reverse also the implicit temporal mapping automatically activated in temporal judgment tasks.

In the second part of this session we focused our attention on a particular but dramatically important cultural variable: language. We asked if people who talk about time in a different way (i.e. use different metaphors) also think about time differently. This question has conducted us back to Benjamin Whorf and his famous *principle of linguistic relativity.* More specifically we wanted to know if, once one has reasonably excluded any significant influence of other cultural variables, grammatical and lexical differences encoded in metaphorical (spatial) expressions of time in different languages can shape the temporal set of concepts of a community of speakers. Once again, the answer seems to be yes, it is possible. We reviewed different experiments that show how speakers of different languages rely upon differnt spatial schemas for temporal reasoning according to particular metaphorical expression provided by their language. In particular, we have seen how language can shape the way we think about duration even in low-level psychophisical tasks that don't require any linguistic mediation or "thinking for speaking" (Casasanto, 2008; and 11.2 in this thesis). Moreover, we could see how subjects exposed to unusual metaphorical temporal expressions, typical of other languages, produced experimental results that are statistically indistinguishable from the results given by native speakers of those languages. These training experiments strongly support the causal role of language in shaping conceptual representations of time, independentrly of other cultural parameters.

Eventually, these compelling evidences that show the effect of cultural and linguistic variables on basic cognitive processes that underlie our (metaphorical) representation of time, have brought us to consider the effectiveness of some radical relativistic positions: to what extent language and culture have an active role in shaping our spatial representation of temporal relations? Is the metaphorical space-time mapping grounded in our basic sensorimotor experience, and therefore universal? Or maybe specific cultural and linguistic paramenters are necessary because such a mapping take place?

It seemed reasonable to approach these difficult questions from a cross-linguistic point of view so that we analyse the case of the population of the Amondawa, a tribe who lives in the Amazonian forest of Brazil and whose language, according to recent studies, lack spatial metaphors for time. Do Amondawa use space to think about time also if they do not talk about time in terms of space? This is indeed an ideal testbed both for the strongest version of the principle of linguistic relativity, and for the experiential basis of the primary space-time mapping (Lakoff & Johnson, 1999; Casasanto, 2008). According to Sinha and collaborators (Sinha et al. in press), whose first studied the Amondawa language and culture, the space-time metaphorical conceptual mapping, as it is framed for example in the Ego-moving and Time-moving schema (Lakoff & Johnson, 1999; Boroditsky, 2000), cannot arise from the simple experience of motion-related episodes (Grady, 1997; Lakoff & Johnson, 1999). Untill a temporal domain, which they refer to as 'time as such' has been constructed on the basis of cultural and linguistic practices, there is not a Time Target Domain able to receive the structural mapping from the Source Spatial Domain (Sinha et al. in press). Time as such is the Target Domain, and if this simbolic although primitive idea of time it is not constructed on the basis of language, the metaphorical mapping cannot take place. Sinha and colleagues reported the absence of ego- and time- moving metaphors in Amondawa language, together with the absence in language and culture of *time-based time interval* costructions (see 11.4) as evidence of the absence of the concept of time as such. And, therefore, the absence of a conceptual space-time mapping.

We have suggested that these conclusions should be supported also by sound non-linguistic data, considering the difficulty to infer basic conceptual structures from linguistic analysis only, and the apparent ubiquity of spatial metaphors for time in all the other languages that are not Amondawa (so far). Moreover, the linguistic analysis conducted by Sinha et al. did not consider sistematically how Amondawa talk about duration, which is a fundamental aspect of time which, as many studies suggest (Casasanto & Boroditsky, 2008; Casasanto, 2008; and session 2 of this thesis), is organized in spatial terms. Therefore, together with Sinha and colleagues we tried to complete the linguistic analysis of Amondawa space-time metaphors, considering duration expressions. Unfortunately, we could present only preliminary data which cannot be taken as the basis for a conclusive thought. However, our data show that Amondawa speakers use spatial metaphors to talk about duration, as we do when we talk about a *long* meeting as we could refer to a *long* rope. If this observation will turn out to be correct, claim about the absence of spatial metaphor for time in amondawa language will have to be mitigated. Nevertheless, the observations made by Sinha and colleagues about the absence of Ego- and Time- moving metaphorical construction remain valid, and wait for the support of non-linguistic data.

To sum up, we have been able to provide evidences that significant aspects of our metaphorical conceptualization of time are culture-specifics, and that metaphorical patterns in language can shape our representation of time independently from cultural parameter and sensorimotor experience. On the other hand, the questions about the universality of the space-time metaphorical mapping and its experiential, sensorymotor basis is still open, now more than ever.

Nevertheless, we would like to conclude this session considering under a critical view the proposal made by Lakoff and Johnson about the experiential basis of the space-time mapping, its automaticity and universality. Our remarks wont be based on cross-linguistic or cross-cultural observations, but on the philosophical and epistemological analysis about physical and psychological time proposed in the first part of this thesis, and on empirical results coming from research in developmental psychology.

## 12.1 From literal to metaphorical time

The formation of the space-time mapping, as it has been described by Lakoff & Johnson (L&J), has been extensively presented in chapter Nine. In a few words, according to L&J (1999) the conceptual metaphor Time is Space[126] is a primary metaphor. Like the others primary metaphors (e.g. “Knowing is Seeing”; “Happy is Up”; “Affection is Warmth”; etc. see Lakoff & Johnson, 1999, pp.50-54) the “Time is Space” metaphor “has a minimal structure and arises naturally, automatically, and unconsciously through everyday experience by mean of conflation, during which cross-domain associations are formed” (Lakoff & Johnson, 1999, p.46; but see also Grady, 1997). According to Johnson’s theory of conflation (Johnson, 1997), primary conceptual metaphors emerge in two stages during young-children developmental process: (1) the conflation stage, in which “subjective (non sensorimotor) experiences and judgments, on the one hand, and sensorimotor experiences on the other, are so

[126] Which can be divided in 1) Time is movement in space and 2) Time is extension is space.

regularly conflated – undifferentiated in experience – that for a time children do not distinguish between the two when they occur together." (ibid. p. 46); (2) the differentiation stage, in which "children are then able to separate out the domains, but the cross-domain association persists. These persisting associations are the mappings of conceptual metaphor" (ibid. p. 46). In the case of the Time is Space metaphor, the 'subjective experience' and the 'sensorimotor experience' that are conflated together are, respectively, the experience of 'literal time' and the experience of motion in space (not necessarily subject's motion).

Indeed, for a metaphorical mapping to take place, it's needed the presence of a Source and a Target domain. Of the universality of the sensorimotor experience of motion through space, the Source domain, there are very few doubts. On the other hand, we have some doubt about the universality of what L&J called the experience of 'literal time'. Is human primary (non metaphorical, non spatial) experience of time universally framed in terms of *literal time*?

If it would have been easy to understand in what our primary experience of time (or time perception, time sense, see chapter 2-3-4) consists of, it would not have been a central question in philosophy and science for the last 2000 years. L&J have proposed their own solution, called *literal time*. As we have already seen (chap. 9) literal time arise from metonymic process based on the correlation of events. Our literal experience of time, is grounded in other experiences. Namely, the experiences of events and their comparison. ''Literal time is a matter of event comparison'' (ibid. 1999, p. 139). Our primary experience of time is always relative to our 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. Even more precisely: ''The sense of time in us is created by such internal regular, iterative events as neural firings'' (Ibid. 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''' (ibid. 1999, p. 138).

The sense of time, or literal time, provided by the comparison of these regular 'time-defining events' with other events is the Target time of the metaphorical mapping:

"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 will call 'time-defining events': our bodily rhythms, the movements of clocks, and so on. […] For example, we correlate distance traveled with duration."(ibid. p. 151)

Here there is a partial contradiction, or at least a passage that has to be clarified. It is not clear, indeed, if what is correlated (conflated) is (1) the sensorimotor experience of motion with the 'literal time', so that the subjective experience of time, based on event comparison; or (2) the sensorimotor experience of motion with 'time-defining events', such as the bodily/neural rhythms or the movements of clocks.

According to the theory of conflation, sensorymotor experience should be conflated with a subjective (nonsensorimotor) experience (Lakoff & Johnson, 1999); in this case the correct hypothesis should be (1) because, until proven otherwise, the movements of a clock and, for example, the heart beating are actual sensorimotor experiences. Otherwise, the correct hypothesis can be (2), and these 'motion situation' are just particular case of comparison of events (literal time) in which 'time-defining events' are compared with other events marked by sensorimotor experience. In that case, it should be remarked that many of the time-defining events described by L&J are themselves motion situation (e.g. the movement of the clock, the movement of the sun), with a relatively regular motion.[127]

We might think that the story starts to be a little confusing and in smell of tautologisms. Part of the confusion, probably comes from taking movements in space and calling them sometimes 'events' and sometime 'movements'. An 'events' in these cases is simply a movement seen in temporal terms. Instead of the word 'movement' we might use the word 'change' (the Aristotelian *metabolée*), because sometimes we refer to changes that haven't any visual movement for the observer, like sounds, heart-beats or neural-firings (although these changes, in last analysis, take place in space, and can be described as movement in physical terms, as Aristotle already new (see chap. 2)).

[127] But, also the experience of moving toward some objects (and the reverse) can be experienced in terms on repetitive regular movements: e.g. the regular movement of our steps, or the steps of the horse we are riding, etc.

However, in both cases (1) and (2) the literal subjective experience of time, which will be the Target domain of our space-time mapping, is based on events comparison. The comparison of any kind of event against iterative and regular events (which metonymically stand for our temporal intervals). We are going to suggest that such a structured experience of time cannot arise automatically, naturally, on the basis of the only experience and, more importantly, such articulated experience of time cannot be the non-spatialized Target domain of the space-time mapping, because, in order to perform such a event comparison, an 'already-spatialized' time is needed.

I certainly agree that time can be measured only as a relation between events (but I prefer say *changes*, or *movements*). We could see it all across chapter two and four when I reviewed some of the philosophic, scientific and epistemological perspective on the argument. Nevertheless, I think that L&J confounded the way adult, occidental and educated people measure physical time with the first and basic experience of what we have called psychological time (see chapter 4). In fact, measuring the duration of one or more changes/events as a function of the (temporal) succession of others, relatively regular, changes/events is not a trivial matter: children cannot do that until they are 7-9 y.o.

Piaget (1969) has provided a complex picture of how children get to master temporal relations on the basis of events comparison. We have already considered one of Piaget's experiments in chapter 5, and its recent elaboration in chapter 7 (Casasanto et al. 2010). In this type of experiment two colored snails traveled side by side along horizontal paths starting from the same spot at the same time. In some cases they traveled at the same speed and stopped either at the same spot (and time) or in two different spots (and time); in other cases the snails traveled with different velocities and stopped: 1) at the same time (different spot); 2) at the same spot (different time); or 3) at different spots in different times.

When the velocity is held constant children are able to provide accurate temporal judgments. For example, if A moves for 4 second, and B for 6 second, the child (from 3-4 y.o.) will say that B stopped after A and that A moved for a shorter duration than B. However, in this case temporal succession coincide with the spatial, and durations with the displacements. This is not too much different than see only one character moving on a linear path reaching the position *b* after *a*, and *c* after *b*.

We know that things change when the two snails move at different speed: now the child cannot provide accurate answer to temporal question because it is still basing his answer on spatial information. For example, for A= [4 sec and 6 cm] and B= [6 sec and 4 cm], the child will say that A moved for a longer time, and that B stopped before A. In short the reasoning of the child became dysfunctional as soon as actions at different velocities are introduced: "before" and "after" loose all temporal meanings, but maintain their purely spatial sense, simultaneity is denied and the equality of two synchronous durations ceases of make sense (Piaget, 1969). This happens because the child is basing his answer on spatial information, and with the introduction of different velocities succession in space might not correspond to succession in time, and distance covered to duration. According to Piaget, at that stage, not only space is influencing temporal reasoning, but spatial reasoning **is** temporal reasoning. It seems that at this stage, the relation between distance and duration is neither metaphorical nor metonymical, although it is asymmetric in its effects (Casasanto et al. 2010). In terms of the mental operation used to answer questions that adults might call 'temporal', we might say that 'space' is like a *placeholder* for 'time' (substitutes time) until a concept of time will be formed, and temporal operations will be used to answer temporal questions.

Interestingly, this kind of 'substitution' it is not exclusive for spatial succession and displacement. In another experiment, Piaget asked some children to draw strokes on a paper and stopped them after 15 sec. Right after, each child was asked to draw again strokes on another paper, but faster, and stopped again after 15 seconds. Usually children judged the second activity as longer compared to the first, basing their judgment on number of strokes that has been drawn[128] (Piaget, 1969, chap.10, §1)[129] Similarly, when young children (4-8 y.o.) were made listen to a metronome beating first

[128] All the children, bifore the experiment, were able to judge, correctly, the relative length of two temporal intervals which consistei in rapping the table for (e.g.) 20-25 seconds. Older children (7-12 y.o.) correctly reported that the two activity took the same time, showing that they have learn to measure duration independently of the work done.

[129] On the basis of his experiment on the 'inner duration', by means of induced introspection as in this experiment, Piaget claimed that the 'inner duration', far from constituting a direct datum of consciousness as pointed out by Bergson, is the product of a very subtle and highly intellectualized abstraction and cannot therefore be examined directly as a matter of perception.

slowly and then quickly for 15 seconds, they asserted that the metronome takes longer to beat more quickly (ibid.). In other similar experiments (Piaget, 1970, chap. 10, §2), with different conditions and tasks, children based their time estimation on *external difficulties* or on *the amount of work done*; and when children were asked to compare an interval of 30 sec. doing nothing while sitting with crossed harms, with an interval of 45 sec looking at amusing picture, they judged the second activity shorter than the fist one (ibid.). Probably on the basis of the *intensity of the effort made* (waiting doing nothing represents a very costly action!). Similarly, Levin reported that most of the young children (nursery) watching two discs rotating at different speeds for the same time (without displacement) reported that the faster discs went for a longer time (Levin, 1978). In another experiment children based their judgment of duration on light intensity, systematically attributing longer duration to the brightest of two light-bulbs (Levin, 1979).

Therefore, children not only rely on spatial information when they have to answer temporal question, but also on speed, rate, result of work, intensity of work and brightness. We do not want to stress too much the possibility that, in all these cases, time is nothing more than speed, intensity, rate, distance, etc.[130] Even if the answers and the justifications provided by the children in these studies conduct in this direction (Piaget, 1969). However, crucially, there is no evidence for an experience, or measure of time, based on the comparison between the task (event, temporal interval) and 'time-defining' iterating events, as suggested by L&J. In none of these case there is a comparison between the event of the task (snail movement, drawing, activity, on-off of the light-bulb, etc.) and a iterate event, like a bodily or neural rhythm, against which the duration of the task could be defined. Otherwise, also young children would have answerd correctly to the time-estimation tasks presented above. In other word there is not temporal comparison between two co-occurrent events (task and 'time-defining' event), but only the comparisons of a single dimension – greater speed, greater distance, greater effort, grater intensity – between two similar activities (drawing strokes, racing snails, watching light-bulbs).

As suggested by Wittgenstein (among others) time cannot be measured against the passage of time itself, but only agaist another process. That is what we do when we

[130] Should we think that time is put in metaphorical relation with all these domains?

measure the duration of two successive events with a clock or by counting: event A is measured against the movement of the clock's hand; event B is measured against the movement of the clock's hand; the movements of the clock's hand in two different situations are compared. Also in that case the comparison happens between a single dimension (clock's hand displacement), but it is not a dimension which is part of the two events (e.g. drawing lines on a paper at different speed). In other words, we make a judgment about an aspect of two events (duration) on the basis of a different aspect of a different event (process). In principle, it is like deciding which of two blue t-shirt is darker on the basis of the position of our hands, or which of two animals was bigger on the basis of the color of the sky during the two observations. If we put it in this way, we might see why it is not so straightforward that we need to relay on a third process to decide which of two events is longer. And why the child has to learn how to do it. The comparison between events in order to determine the duration it is not automathical and natural as suggested by Lakoff and Johnson.

These studies clearly suggest that there is not a privileged, or some privileged, repetitive event-movements (internal or external) which are used to measure duration and give us our preliminary sense of time (by metonimy). Otherwise why the child do not use it in all the cases presented above, relying instead on comparison of distance, speed and rate, or even in aspects of the activity which are less directly associated with time like effort made or brightness? The answer is twofold: 1) because in most of the cases it works just fine, i.e. the relative duration inferred from these other dimensions lead to correct temporal judgment; in fact in those cases the internal clock is useless.[131] 2) Because the comparison of an event against another event, in order to determine the duration of one in term of the other is a temporal comparison which requires a good amount of temporal (operational) knowledge in order to be performed.

Indeed, the comparison between two movements is the only way to differentiate temporal succession and temporal duration from spatial succession and displacement (or work done, velocity, intensity, rate, etc.). And this is the way time was measured according to the movement of the stars, it is how Galileo was measuring the duration of

[131] Moreover, when the internal clock would be useful, i.e. when the events have different rates or velocity, children do not use it and still rely on other dimensions.

the oscillations of the chandelier against his wrist-beats,[132] and it is the way we usually measure durations. Therefore we might be keen to apply this time reckoning strategy to almost all the living organism as a particular sense. But this way to measure time has to be learnt, it is not grasped from the real world by our intuition, and it is not the product of a "clock-watching comparator" embedded off-the-rack in our nervous system as proposed by the internal-clock models.[133]

Time, in terms of homogeneous measurable extension, independents of events and its characteristics, that can be put in relation with time in order to measure velocity ($v= s/t$), is of course a useful abstraction, but life can be managed also without it. That's why we do not need to put an internal clock in the brain of animals, because what we might call temporal behavior can be performed on the basis of direct comparison of non-temporal characteristics of events. Indeed, in the natural environment, duration usually correlates with the amount of effort or work done, and velocity can be grasped independently of time (Piaget, 1969). Even if animals have such an internal clock, they would not be able to read it, and they actually don't need it until they are moved into a laboratory of psychology.

According to Piaget, what we call time is the *co-ordination of motions at different velocities*. And such a co-ordination is a mental operation not easy to grasp by the mind of the child, who goes through different stages of time understanding. If displacement is a spatial concept that doesn't imply motion, we need the notion of

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[132] See chapter 4.

[133] We have already presented arguments against the internal clock model (Chap. 3-4), but considering the studies presented above, new issues can be taken into account. We have seen that theorists of the internal clock explain these results pointing out that high velocity, intensity, rate, etc. speeds-up the pacemaker (or intervene in other part of the clock such as gate or accumulator) dilating the perceived duration. Nevertheless, this theory does not explain why: 1) in children (4-10 y.o.) this effect cause dramatic errors in duration evaluation and in 'adults' (we may assume from 12 y.o.), only imperceptible (although constant and significant) augmentation of the temporal estimation or errors in judgment of sub-second or very similar durations; 2) why until 7-8 y.o., children consider fast movement to last more, but after that age they start consider fast movement to last less (always intuitively, regardless which of the two movements actually last more), and around 10-11 y.o. they start to evaluate the duration independently of the (only) velocity? Do velocity "speeds-up" the clock before, then "speeds it down" and finally ceases its effect? We think that considering duration experience as the product of an intuitive or operative psychological construction explain these results better than reduce it to mere physiological processes.

*velocity*,[134] in order to understand time. While the concept of time is not grasped operationally, the displacement or the work done is confused (identified) with duration, and the spatial order is confused (identified) with the temporal order. The construction of time proper, therefore, begins with the correlation of velocities, be it in the case of human activity or of external motion.

As sustained by Piaget, space is a system of positions (placements) and changes of position (displacements); time however, is a system of co-positions (co-placements) and co-displacements.

Consider in the next figure, for example, the spatial sequence A-B-C, that might represent three stages of the diminishing level of a liquid in a flask.

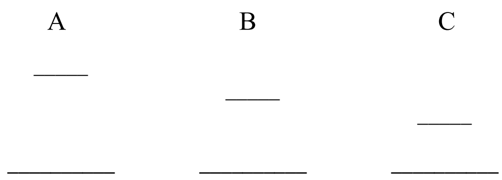


Fig. 18

The differences between the three states are analyzable in terms of angular relationships, without taking velocity into account. In other words, what happen between A and B, or B and C is not important. Let us consider now the figure 19, which represent a temporal sequence of two movement (i.e. different states of level of liquid in two different flasks at different time, one decreasing and one increasing):

[134] Moreover, before the temporal order has been constructed, the idea of velocity is often bound up with that of overtaking (i.e. with a purely spatial intuition involving a change in the respective positions of two moving objects).

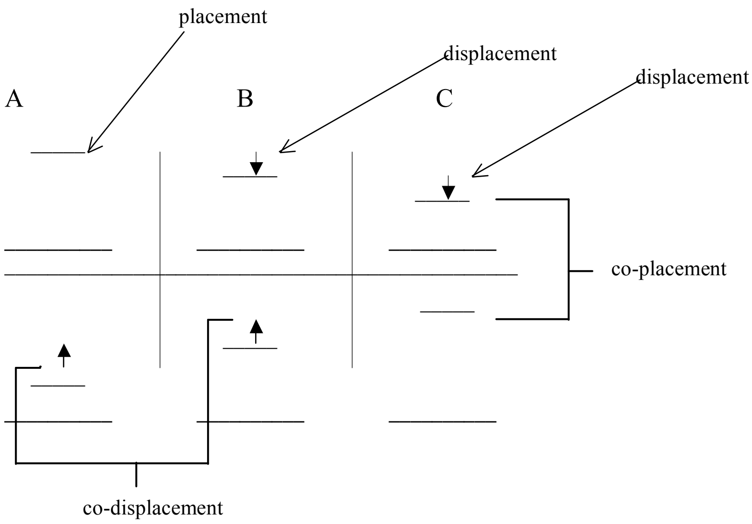


Fig. 19

Here, the ‘boxes’ A, B and C represents parts of a temporal sequence and not only a spatial sequence. Therefore, it is the relative velocities of the object between state A and state B, or between state B and state C, that determine in which box any spatial state is represented. If, for example, the object in II were to have moved faster, it would have produced the situation shown in Fig 20

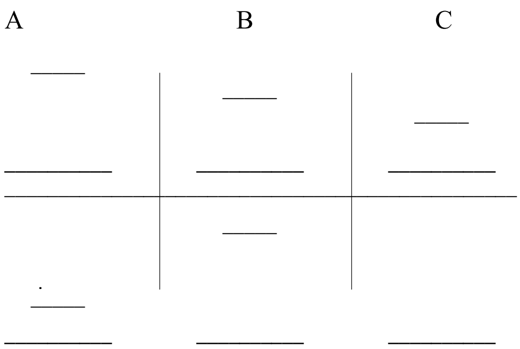


Fig. 20

In this case, in the box B, there is the spatial state that was before represented in C (and the spatial state before represented in B is not represented anymore). We can say that, considering together, in the same act of perception, two spatial states of two different movements[135] (co-placement), is the first step to differentiate a temporal sequence from a spatial sequence. Thus, it can be said that each co-placement defines a simultaneity; each co-seriation of distinct co-placements defines a time sequence; and each co-displacement defines duration and velocity (See again fig. 19).

Now, imagine that I and II, instead of two flasks, are two snails moving along parallel path with different velocity and for different time. During the 'race' we take 5 pictures of the snails that will tell us their position in different moments of the race, so we will have the following sequence:

$$\mathrm{I}_1 \longrightarrow \mathrm{I}_2 \longrightarrow \mathrm{I}_3 \longrightarrow \mathrm{I}_4 \longrightarrow \mathrm{I}_5$$
$$\mathrm{II}_1 \longrightarrow \mathrm{II}_2 \longrightarrow \mathrm{II}_3 \longrightarrow \mathrm{II}_4 \longrightarrow \mathrm{II}_5$$

Than we can indicate as a letter with an accent the duration between one stage and the other:

$\mathrm{I}_1 \xrightarrow{a'} \mathrm{I}_2$; $\mathrm{I}_2 \xrightarrow{b'} \mathrm{I}_3$; … etc.

$\mathrm{II}_1 \xrightarrow{a'} \mathrm{II}_2$; $\mathrm{II}_2 \xrightarrow{b'} \mathrm{II}_3$; … etc.

And with a letter without accent the cumulative durations:

$\mathrm{I}_1 \xrightarrow{b} \mathrm{I}_3$; $\mathrm{I}_1 \xrightarrow{c} \mathrm{I}_4$; … etc.

$\mathrm{II}_1 \xrightarrow{b} \mathrm{II}_3$; $\mathrm{II}_1 \xrightarrow{c} \mathrm{II}_4$; … etc.

When the different stages of I are correlated with the stages of II, it produces a new system of relations between $\mathrm{I}_1$ and $\mathrm{II}_1$; $\mathrm{I}_2$ and $\mathrm{II}_2$; etc. that is a relation of simultaneity, or null succession that can be represented as:

[135] To consider together, in the same act of perception two different spatial states of the same movement is impossible by definition.

$I_1 \overset{0}{\longleftrightarrow} II_1$;  $I_2 \overset{0}{\longleftrightarrow} II_2$;  … etc.

Then, on the basis of this simultaneities (co-placement) we can seriate the different stages according to a "before" and an "after" that has a temporal meaning which is distinct (independent) from the spatial one:

$$\begin{tikzcd}
I_1 \arrow[r, "a"] \arrow[d, leftrightarrow, "0"] & I_2 \arrow[r, "a'"] \arrow[d, leftrightarrow, "0"] & I_3 \arrow[r, "b'"] \arrow[d, leftrightarrow, "0"] & I_4 \arrow[r, "c'"] \arrow[d, leftrightarrow, "0"] & I_5 \arrow[d, leftrightarrow, "0"] \\
II_1 \arrow[r, "a"'] & II_2 \arrow[r, "a'"'] & II_3 \arrow[r, "b'"'] & II_4 \arrow[r, "c'"'] & II_5
\end{tikzcd}$$

We obtain a succession of co-placements ($I_1II_1$; $I_2II_2$; $I_3II_3$; etc.) and co-displacements (a; a'; b'; etc.), which constitute a temporal succession and temporal durations that have no spatial meaning.

This coordination of motions at different velocity is what we call time, and according to Piaget it is based on operations of 'grouping' in which successions of simultaneities (co-placements) and durations (co-displacements) are considered together, and colligated/compared to each other as in a group. This definition of time might remind the words of Bergson saying that when we are measuring duration we are just counting simultaneities (which are the intersection of time and space for the French philosopher). But, according to Bergson, the duration between two simultaneities could derive only from the 'real duration' determined by the succession (without externalization) of our states of consciousness (See chapter 2). On the other hand, Piaget has suggested that physical duration is constructed on the *co-ordination of displacements*, and internal psychological duration (*inner* duration) follows the same rules:

"But How precisely does the child develop his conception of inner duration? Let us imagine a creature who, from birth to death, does the same work, for instance building a long wall, at the same speed. His psychological time would coincide with his physical time: since the work proceeds at a constant rate, he could judge the durations simply by the size of the wall, and intervals simply by differences in that size. As soon as actions cease to be uniform, however, and different velocities are introduced, not only does psychological time become divorced from physical time, but different speeds of rhythm introduce new complications into the evaluation of duration and into the order of successions. We might even claim that differences in velocity dominate the problem of inner durations, in exactly the same way as they dominate the problem of physical durations. […] Hence the problem of psychological time, like that of physical time, reduces to the co-ordination of motion and velocities or, in our particular case, to the co-ordination of actions and the rate at which they are performed" (Piaget, 1969, p. 251-252)

And that's precisely what we do when we coordinate a given event with a 'time-defining' event that has a homogenous rate. This is what we do when we count in our mind to measure the duration of two different sounds, or what Galileo did measuring the duration of the oscillation of the chandelier with his wrist-beats. But this is also what a child cannot do, until he learns the metal operation necessary for co-ordinate actions and the rate at which they are performed.[136]

[136] Piaget writes: "It follows that children evaluate the duration of their own actions in the same way that they evaluate physical time. Here, as elsewhere, the child advances from intuitive and irreversible egocentrism to operational groupings or to the level of objective and reversible co-ordinations in which the ego is but one element among others. Now this explains why young children has introspective problems with the evaluation of time, and why older children are able to dissociate psychological time from physical time to discover the correct relation between time and velocity. In young children, the egocentric, i.e. the immediate and irreversible character, of thought, proves an impediment to introspection: the awareness of an action begins with the awareness of its results, and it is not until later that decentrations of comparisons lead the child back to the action itself. Hence small children begin by judging the duration of an action by its quantitative results (number of strokes drawn) or by the work done (the respective weight or size of the pieces of lead and wood) rather than by the speed. It is only when their actions produce no external results (e.g. waiting or looking at pictures) that they judge time like adults, i.e. in terms of boredom or interest, but without giving any reasons and in the firm convinction that they are producing objective judgments – once again for lack of introspective powers. Now, the same factor that impede introspection in small children and hence explain their realistic evaluations of the time of actions, also prevent them from grasping the inverse relation between the rapidity of an action and its duration, and consequently from fitting velocities into a coherent time-schema. In effect, thinking that 'quicker' signifies 'more time' as small children do, both on the physical and also on the psychological plane, is simply to liken the impression of the speed of an action (an impression which is naturally conscious because the speed is intentional) to its situations, judged, not during the action itself […] but after the event and by its results: the greater the distance covered or the work done, the longer it must take. […] With the appearance of articulated intuition at stage II, quicker become equated to less time,

Indeed, given the complexity of temporal relations as are presented by Piaget (that here we considered just in part), it should not surprise us that the child manage quite late to master what for an educated adult seems to be just the basic temporal knowledge. Before that, the child relies on what Piaget has called the 'direct intuition' of time, with the results that we have seen above (e.g. snails experiment). The construction of correct temporal relations based on the co-ordination of motions at different velocities is a slow process during which the child can acquire a respectable temporal vocabulary without cognitively grasping the temporal relations he's talking about:

"… a child cannot be said to have grasped the simultaneity of, say, $I_1$ and $II_1$; $I_2$ and $II_2$, etc. simply because he explains that they happened 'at the same time', or 'together' – he must also have realized that duration $I_1I_2$ is equal to the duration $II_1II_2$. Similarly, the child cannot be said to have grasped the fact that $I_2$ precedes $I_3$ simply because he explains that it 'come first' or even that 'it contained more water', etc. he must also grasp that the duration $I_1I_2$ or $II_1II_2$ is shorter than the duration $I_1I_3$ or $II_1II_3$ … succession and simultaneity are not grasped operationally unless they lead to the construction of a system of colligated durations, much as durations are not grasped operationally until they can be placed in one to one correspondence with a system of successions and simultaneities" (ibid. p. 35)

We have seen how, in some cases, direct intuition lead to the correct conclusion. For example when two bodies have the same velocity and start from the same point at the same moment, but do not stop simultaneously. In this case it will be correctly concluded that the one that stop first went for a shorter duration than the one that stops after it, but this is simply because it has covered a shorter distance. Direct intuition does not rely on co-ordination or the grasp of ratios, but infers on the basis of comparisons of a single dimension – greater speed, greater distance, greater effort – or of the direct comparison of similar trajectories. Similarly, the direct intuition of inner duration leads to the correct conclusion when one of two tasks, performed with equal speed, is

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because introspection now helps the child to distinguish between actual durations and the results of actions. This leads to the reversal of the previous error and to the intuitive regulation. Finally, in the most advanced subjects, introspective regulation is joined to correction based on operational reversibility, and so helps to turn psychological time into a particular case of that general co-ordination of motions and velocities which, as we saw, goes into the construction of time in all the spheres we have been examining." (Piaget, 1969, pp. 253-254) terminated before the other. The child would indicate the one that stopped first as the one that took a shorter time. But also in this case, as in the case of the two bodies moving with equal velocity, for which the duration was inferred by the covered distance, shorter duration will be inferred from the fact that less work was done in the task that stopped first. As soon as velocities of bodies or the rate of work differ, direct intuition can no longer lead to correct conclusions, since duration has become distinct from distance covered or work done, and must now be constructed from the co-ordination of the motion themselves.

To conclude, it is worth to consider that, in order to co-ordinate simultaneities and displacements, and compare previous durations between them (elapsed duration that are not present anymore), the child requires the reversibility of thought:

> "To grasp that the duration a (=$II_1II_2$) is shorter than the duration b ($I_1I_3$=$II_1II_3$) once the water has reached $II_3$ (=$I_3$), the child must, in effect, go back in thought to $II_1$ (=$I_1$) and hence be able to traverse the intervals $II_1II_2$ and $II_1II_3$ in either direction. But in that case, it is thought alone which become displaced" (ibid. p. 58)

In order to compare different durations that appear in a sequence, these durations have to be considered together. This could seem a trivial cognitive task, but it is not: it might need a spatialized concept of time in order to be performed, namely the capacity to go back and forth in time as in space and to consider synchronically, different moments of time which are not synchronous. This is possible only if time is already spatialized as a homogenous medium in which intervals of time can stay side by side as the pearls in a necklace (Bergson, 1889). This process has been called 'grouping' by Piaget [137]. It is at the basis of reversible thought and employed also for the construction

[137] According to Piaget (1969 p. 22) "reconstructing events in their correct sequence presupposes an ability to go up and down the time scale, i.e. to construct a series A → B → C … such that the arrows can stand for 'precedes' as well as for 'follows'. Now, in establishing this logically reversible series based on the irreversible course of events, our subjects must have sufficient mental mobility to choose from all the possible sequences only those in which the arrows can be given a consistent interpretation. […] This possibility to go back and forth across temporal sequences allow to consider a duration as a symmetric relation between two moments (i.e. the duration between A and B is the same that the duration between B and A) and consider it like different portions of an homogeneous medium. Portions of time that can be compared to each other as if it's possible to consider them in a unique perceptible situation like portions of space."

of the concept of numbers. The fact that considering different successive simultaneities together is not a trivial process, but a sign of spatialization of thought, has already been pointed out by Bergson:

“For if time, as the reflective consciousness represents it, is a medium in which our conscious states form a discrete series so as to admit of being counted, and if on the other hand our conception of number ends in spreading out in space everything which can be directly counted, it is to be presumed that time, understood in the sense of a medium in which we make distinctions and count, is nothing but space.” (Bergson, 1989. p. 91)

Indeed, that time has to be spatialized in order to be measured it is clear across many philosophical traditions (chap. 2), and even Benjamin Whorf suggested something similar to the Piagetian grouping when he distinguished between “physical aggregates” (e.g. ten men on the street) and “metaphorical aggregates” (ten days) (see 11.1). According to Whorf, Hopi Indians did not think in terms of metaphorical aggregates, therefore did not spatialize time. We do not now if it is true, but the difficulty to understand that a ‘piece’ of duration, that *has already been*, can be taken and compared to a current duration is well shown by one of the little participants of Piaget’s experiments:

“Mog […] had this to say on the subject of duration: ‹‹ When we’ve emptied these three space ($I_{1-4}$) only this one ($I_{4-5}$) is left, so we can’t empty these three spaces ($I_{2-5}$) all over again››. In other words past duration cannot be determined simply because it is past! Or, to put it differently again the irreversible intuition of time prevents its reconstruction by reversible operations! And Gen was, in fact, so skeptical about the feasibility of his task that he was quite unperturbed by the disconformity of his two series, maintaining that $I_7$ (empty) could have been drawn before $II_7$ (full)” (Piaget, 1969, p. 28)

To sum up, we provided evidences that support:

a) Literal time, as a temporal comparison of events do not arise automatically from the experience of the world, but is a cognitive operation that has to be learnt by the child. The child at the beginning it is not able to consider two movements (changes, actions, repetitive events, etc.) simoultaneously, and compare them independently of their rate.

b) Once the child is able to perform such a temporal events-comparison (co-ordination of motions with different velocities velocities, or co-ordination of activities with different rates), time is already spatialized (at least in Bergsonian terms), or at least based on mental operation that are originally spatial. As summarized by Piaget: “it should be stressed that while co-seriation necessarily leads us to time (once achieved it is the very ‘scheme’ of time), it is based on purely spatial relations (co-placement) and kinetic relations (co-displacement), though involving at least two motions.” (Piaget, 1969, p. 29).

c) As suggested by Wittgenstein (see epigraph) the description of the temporal sequence of the events is possible just through another process: before of grasping temporal relations in operative terms, time is intuitively grasped by the children on the bases of other process and parameters that are not temporal: distance, velocity, rate, brightness, intensity of work, result of work, etc. In that period the relationship between time and all those domains is neither metonymical nor metaphorical, in the sense that neither mapping nor part-whole interaction is taking place between conceptual systems. The relationship between space and time is asymmetrical (Casasanto et al. 2010) not because there is a metaphorical mapping going on, but because space works as a *placeholder* until a concept of time is constructed.

On the basis of the Piajetian theory, the results of the experiments with children I have suggested that the primary subjective experience of time should be something different from the ‘literal time’ proposed by Lakoff & Johnson. If the Piagetian time based on the coordination of displacements/actions at different speed/rate, it is equivalent to the ‘Time as Such’ proposed by Sinha and colleagues, and therefore a good candidate to be the Target domain of the metaphorical mapping, is an open question.

Hallpike (1979), has shown that not all the societies have grasped the stage of operational thought where reversible operations, necessary for a full understanding of temporal relations, are possible. He also reports the work done by the anthropologist M. C. Bovet among illiterate Algerian adult peasants. When these people were tested in experiments similar to the ‘Snails Game’, performed quite similarly to the children tested by Piaget: they answered to temporal questions on the only basis of the distance covered, which suggests they did not think about time in terms of co-ordination of motions. Bovet writes:

“Yet we have noted that the general error consists in judging duration according to the length of the tracks in the experimental situations, and not according to the speed of the displacements. In the same way, in the accounst of journeys used as an introduction [to the test], a longer duration was always ascribed to the person who has covered the longer distance. This dominace of length seems to show that, in the interrelationship of factors at work there – temporal and spatial orders, speed, length and duration – the spatial dimension is the best structured aspect and accordingly the most easily differentiated. Even the temporal order reveals itself as still closely attached to the spatial order, as we have observed.” (quoted in Hallpike, 1979)

Here is how Hallpike explains these results:

“Thus, the fundamental distinction between primitive, pre-operatory conceptions of time and those of concrete and formal operations, which we employ in many areas of our thinking, is that primitive time is based on sequences of qualitatively different events, such as those of the seasons or of daily activities. In such cases it is evident that these qualitative sequences may be peculiar to each community, giving rise to an identification of ‘this time’ with ‘this place’, so that it becomes impossible to co-ordinate duration, simultaneity and succession from place to place, while the flow of time will appear to proceed at different rates depending on the nature of the activities” (Hallpike, 1979, p. 383)

It seems to me that what is missing in the conception of time described by Hallpike is exactly a homogeneous flux independent of the events that happens in it. The flux of time that Newton called absolute, Bergson ‘spatialized’ and to which Sinha and colleagues refer to as ‘Time as such’. To use Sinha’s terminology, the time described by Hallpike is organized upon “Even-based time intervals”, were duration and temporal succession cannot be considered independently of the event that define them. Can temporal relations (excluding the cases where duration and displacement can be considered together)[138] be understood in terms of space even without a concept of Time as Such? Hallpike' analysis suggests that it might be the case:

"This mode of time-reckoning inherently involves incommensurable periods, and because the sequence of those customary and concrete events used for time reckoning is usually cyclical in nature, it is also unvarying, which adds to its irreversible and static quality, static in the sense that each event is uniquely linked with its predecessor and successor. Such a sequence of events is thus closely comparable to a landscape, with each landmark in a fixed relationship with every other. Relations of time can therefore be comprehended by spatial concepts such as *near*, *far*, *beyond*, *behind*, and so on. In addition, as Bovet points out, the fact that spatial representations may be better structured than those of time will be further reason for the 'spatialization' of time". (Hallpike, 1979, p. 383)

Wheter or not the metaphorical space-time mapping is possible before a reversible operational concept of time is acquired is an open question for future research.

[138] In these cases the space might be see as a simple placeholder for the concept of time

# 13. General conclusion

Chapter 1 began with a famous expression of Albert Einstein, according to which space and time are modes by which we think, not conditions under which we live. Einstein thought that time in the physical world isn't a basic parameter, but a useful abstraction derived from distance and velocity - and, therefore, relative to distance and velocity. This relativistic view was already clear in Giordano Bruno, Liebniz and, as we have seen, even in Augustine (Chapter 2). In this view, time is a relation between events, and like most relations we might think of, it is not a natural kind but an act of thought. Aristotle was aware of this, saying that probably there is not time without a mind (soul) that 'counts' the "number of changes with respect to the before and after" (see 2.2); Augustine pushed it further, sustaining that if time exists it is more likely to be found in our soul than in the external world[139] (2.4); Bergson radicalized this claim pointing out that the only 'real time' is the time (duration) of our consciousness (2.8).

I'm concerned about the real nature of time only to the extent it can help to understand the way we think about it. The ontological question "What is time?" was not of direct interest in this thesis, which has been focused on the epistemological question "How does the thinking mind come to have a concept of time?". Although I have been able to construct an opinion about it, I certainly prefer to be agnostic about the ontological existence of some sort of "physical time." I would limit myself to take note that, however, even in physics there is not a univocal definition of time: time has extension but not direction in mechanics, and has direction but not extension in thermodynamics. It is continuous in mechanics and thermodynamics but discontinuous in quantum physic. Time is a fundamental parameter in a world composed by *strings* and can be ignored in a world organized by *loops.*

This simple statement of facts should discourage any attempt to understand what we have called 'psychological time' on the basis, or even as a reflex of physical time. A

[139] But we have seen how another interpretation of the famous 'distentio animi' is possible (see 2.4).

reflex of what exactly? The Newtonian time? The thermodynamic one? Quantum? Or maybe cherry picking some aspects of it, here and there, according to the results of our experiments and observations? Actually, given the lack of consensus about the physical description of time we may convey that the time we know better is time as it is represented in our mind, of which, at least, we can have direct experience (see Chapter 4). In the first part of this thesis (Chapters 3 and 4) we concentrated our efforts on challenging the widespread attitude in psychology and neuroscience that we perceive time directly from our experience of the world as we perceive colors on the basis of the experience of electromagnetic radiations and sounds on the basis of pressure waves. As simply observed by Ornstein (1969), if time were a sensory process like vision, we would have an organ of time experience such as the eye. I think this is true also for the popular and widespread metaphor of the neural-clock model, and I hope to have provided enough good reasons to persuade the reader that thinking about temporal experience as the product of direct perception of some sort of physical time is of no help in understanding how time is represented in our mind (Chapters 3 and 4).

Once established that our knowledge of time cannot derive from the perceptual experience of time itself, one might start to think that it should depend on something else. We considered the hypothesis suggested by cognitive linguists (Lakoff & Johnson, 1980; 1999), according to which we think about time in terms of space. That time has been, more or less explicitly, 'spatialized' by the majority of the western philosopher and scientists was clear from our review on the argument (Chapter 2). From Plato to Newton and Kant, the heterogeneous flux of time has been stopped, and divided homogeneously into a succession of motionless states in order to be measurable, quantifiable, like space. The theory of cognitive linguistics suggests that a similar spatialization happens in each single mind, otherwise we would not be able to think about time the way we do (Chapter 5). More specifically, our concept of time is constructed metaphorically on the basis of our experience of spatial relationships. Such a metaphorical construction is evident if we consider how people talk about time across many different languages. In English, for example, we can look *back* to our happy moments, look *forward* for a brighter tomorrow, feel stressed when a deadline is *approaching* us, take part in *long* meetings or allow ourselves a *short* vacation.

According to the metaphor theory of cognitive linguistics, we do not only talk about time in terms of space, but we also think about time using pre-existent spatial conceptual structures. As suggested by Lakoff & Johnson, on the shoulders of illustrious forerunners as Gianbattista Vico or Friedrich Nietzsche, metaphors are first of all a matter of thinking, even more so than language. Domains of experience that we may call abstract, such as *time*, which cannot be structured upon stable sensory-motor basis (we cannot perceive time!) are represented in our mind using the conceptual structures of more concrete experiences, such as spatial relations.

The theoretical statement according to which we need space to think about time, initially proposed on the basis of widespread and consistent linguistic patterns, has been recently supported by rigorous psychological experimentation (Chapters 5 and 7). Indeed, to sustain that patterns in language reflect the way we think, evidence based on linguistic data only are not enough (Casasanto, 2009a). This lack of evidence has been filled by a large number of psychological and psycholinguistic studies which show that space and time are strictly coupled in the human mind. Experiments show that people's temporal judgments are influenced by spatial information, independently of whether they are using language or not (Chapter 7). More specifically, the subject cannot help relying (at least partially) on spatial information that is irrelevant for their tasks, when they are reasoning about time. For example, in a simple task of duration estimation, where the subject has to estimate the duration of a line, lines that are longer in space are systematically estimated to last longer than lines that are shorter in space, even if all the lines have the same average duration (Casasanto & Boroditsky, 2008). Moreover, the fact that people are using spatial representations when thinking about time emerges clearly observing how co-speech gestures vary according to the metaphors used in their natural language. For example, the Aymara, who talk about the future as being behind them, and the past in front of them, produce temporal gestures that respect the mapping used in their language. English speakers produce instead the reverse gesture-pattern (Núñez & Sweetser, 2006). And these are only a few of several pieces of evidence which suggest that spatial conceptual structures are active when we think about time.

This kind of evidence, however, leaves open an important question: even if it has been shown that space and time are linked in our mind, and that spatial conceptual structures are likely to be active during temporal thinking, how do we know that the relationship between space and time is metaphorical? Indeed, not only Metaphor Theory (MT), but also other psychological approaches have posited a close relationship between the concept of space and the concept of time. Nevertheless, this relationship doesn't have to be based on metaphorical processes.

In the second section, we have considered one of these theories, proposed by Vincent Walsh and called ATOM (A Theory of Magnitude). According to ATOM (Chapter 6), space and time are represented in the brain and mind by a common analog magnitude system (Walsh, 2003). Such a common metric can explain directly experimental results where spatial information interferes with temporal magnitude judgments of duration, which are some of the most compelling evidence for the link between space and time in mind. Moreover, this space-time relationship at the level of magnitude computation can be generalized, and become the basis of the link between the two dimensions beyond magnitude judgments. This elegant model can explain all the cases of spatial influence on temporal reasoning that we have reviewed above (as well as patterns in language) without positing any metaphorical relationship at the conceptual level. How can we make a distinction between ATOM and Metaphor Theory, in order to find out which of them is more likely to be true?

Implicit in ATOM is the assumption that time, space, and number are symmetrically interrelated. Indeed, if these dimensions are all manifestations of a common magnitude metric, they should show cross-domain, cross-dimensional interaction, and there is no *a priori* reason to posit that one dimension should depend asymmetrically on another. On the other hand, Metaphor Theory makes a different prediction: if the relationship between space and time is metaphorical, than time should depend on space more than the other way around. The relationship should be asymmetric.

Indeed, according to cognitive linguists, every 'conceptual metaphor' is based on an asymmetric relation between the more abstract Target Domain (e.g. time), that is structured in terms of a more concrete Source Domain (e.g. space). In other words, the conceptual mapping at the basis of conceptual metaphor goes from the concrete to the abstract in the large majority of the cases (see Chapter 5). This asymmetry is once again clear if we look to patterns in language: in English (as in many other languages) we talk about time in terms of space much more often than the opposite.[140] If this asymmetrical pattern can also be found for the relationship between space and time at the conceptual level, it can be considered as a evidence to accept MT and discard ATOM.

To find out, we considered previous work that tested the mutual relationships between spatial and temporal processes of thought (Casasanto et al. 2010; Casasanto & Boroditsky, 2008; Boroditsky, 2000). All these studies suggest that space and time are asymmetrically related in our mind: in tasks of cross-dimensional interference, space influence time more than time influence space. For example, Casasanto & Boroditsky (2008) asked to their subjects to estimate the either spatial length or the duration of growing lines (with different lengths and durations) on a computer screen. In estimating time, the amount of displacement of each line influenced the judgments of duration, so that – for stimuli of the same average duration – lines that extended shorter in space were judged to take a shorter time, and lines that extended longer in space were judged to take a longer time. On the other hand, for stimuli of the same average spatial length, spatial estimation was not affected by the actual duration of the lines. In other words, people were unable to ignore irrelevant spatial information when making judgments about duration, but not the converse. The authors concluded that, as in language, at the conceptual level time also depends on space more than vice-versa.

In the first experimental study presented in this thesis (Chapter 8) we took a skeptical position toward this conclusion. Maybe these results could be explained otherwise. It might be possible to reconcile these results with ATOM by positing that in previous studies, space influenced time asymmetrically because space was the more perceptually salient dimension in the stimulus. Following Garner (1976), Casasanto & Boroditsky (2008) asked participants to judge different dimensions of the same stimuli (e.g., the spatial or temporal extent of a line). Thus, people had the exact same perceptual input during space and time judgments. But this does not guarantee that the dimensions were equally perceptually salient: it is possible to *see* the spatial extent of a line, but not its duration. It is possible to perceive space (i.e. spatial variation), but arguably it is not possible to perceive time directly through the senses (Ornstein, 1969). As we have sustained above, temporal experience is not a sensory process, and there is

[140] One of the few examples of temporal metaphors for space is when we talk about the distance of planets and stars in terms of light years.

not an organ of time, such as the eye, that can be perturbed by external stimulation. Comparing space and time in a psychophysical task, therefore, we have to take into account the different perceptual salience of the two domains. The asymmetry between space and time might be in the world that we perceive, and therefore in the stimuli of our experiments, instead that in our mind. Would the space-time asymmetry persist in psychophysical judgments if differences in the perceptual salience of space and time in the stimulus are definitively eliminated?

In the study presented in Chapter 8, we eliminated differences in perceptual salience by eliminating perceptible variation in the critical dimension (space or time), altogether. We tested whether the implicit spatial information encoded in object nouns can influence estimates of time (in Experiment 1), and whether the temporal information encoded in event nouns can influence estimates of spatial length (in Experiment 2). Participants saw words presented one at a time and reproduced either the duration for which they remained on the screen or their spatial length, using mouse clicks as in Casasanto & Boroditsky (2008). In the duration estimation task (Experiment 1), the target words named objects of various spatial lengths (e.g., *pencil*, *clothesline*, *footpath*). All target words had the same number of letters in Dutch, and therefore the same physical length on the screen. In the spatial length estimation task (Experiment 2) the target words named events of various durations (e.g., *blink*, *party*, *season*). Again, all target words had the same number of letters, but they were presented with a varying number of spaces between letters (1-9 spaces), stretching them out to different spatial lengths on the screen. Word meanings were irrelevant to the length and duration estimations. We expected, however, that participants would read the words while viewing them, and activate their meanings (voluntarily or involuntarily). Presumably, the meaning of an object noun typically includes a representation of the object's spatial form, and the meaning of an event noun a representation of the event's duration. If internally generated spatial and temporal representations cued by words are sufficient to modulate estimates of experienced duration and spatial length, then we should observe cross-dimensional interference. Following metaphor theory, we predicted that the cross-dimensional interference should be asymmetric, even in the absence of cross-dimensional differences in perceptual salience: spatial representations cued by object nouns should modulate estimates of their duration more than temporal representations cued by event nouns modulate estimates of their spatial extent on the screen.

This is indeed what we found. When participants reproduced the duration for which an object noun remained on the screen, their estimates were influenced by the implicit length of the word's referent. Words that named shorter objects (e.g., *cigarette*, *pencil*) were judged to last a shorter time, and words that named longer objects (e.g., *bench*, *highway*) to last a longer time. By contrast, when participants reproduced the spatial length of an event noun, the duration of the word's referent did not influence judgments of spatial length.

We interpreted these results as a further evidence in favor of metaphor theory: even eliminating any perceptual variation in the stimuli, and eliciting internal representations of the irrelevant dimension, we still have the same asymmetrical relationship that were found in the previous studies: space influences time more than vice versa. This result, once again, support metaphor theory and challenge ATOM.

Compelling evidence, therefore, suggests that our concept of time is organized metaphorically in terms of space. According to the classic version of MT (Lakoff & Johnson, 1980; 1999) humans are not born with a space-time conceptual metaphor embedded in their minds or brains, but they have to build them up on the basis of experience. In this view, the child learns to associate time to space during the frequent motion-situation in which, for example, a longer distance covered corresponds to a longer duration. In this situation space can easily stand for time, and we can use the former to think about the latter: if more distance corresponds to more duration, less distance to less duration, I can compare durations just by comparing the corresponding distances (for equal speed), before in space is also before in time, and so on. When this space-time association is generalized to all the temporal experience (even when motion and space are not involved) the metaphorical conceptual mapping is formed. The process of mapping organizes our embryonic and unspecified concept of time in terms of spatial relations, and allows us to think about time the way we do (e.g. with a specific direction; according to relations of containment and succession; as a continuous flux of events; a linear unidimensional path; etc. see Chapter 5)

This general view has two important implications: 1) there is a non-metaphorical concept of time that becomes associated with space through experience. Lakoff and Johnson called it 'literal time' and it is based on event comparison. 2) Our experience and representation of time in terms of space is universal, because all human beings share quite similar (basic) sensorimotor experience of the world.

Nevertheless, around the world, time seems to be represented differently in different cultures, and people use different metaphors and expression to talk about it. Can differences in cultural practices affect the cognitive processes we use to represent time, independently of our sensorimotor experience of the world? Is our metaphorical conceptualization of time (even at the level of implicit conceptual mapping) different depending on the culture in which we live and the language we speak?

Our contribution to the studies of cultural relativity of the space-time metaphorical mapping has considered the case of the 'lateral time-line' (Chapter 10). In English we can talk about the flow of time as if past events are 'behind' us and the future events 'in front' of us. In fact, we can look *back* to our childhood or hoping to have a bright future *in front* of us, and we can push a meeting *forward* or *back* a couple of days. Psychological experimentations have shown that we often represent the succession of events in our mind using this front-back spatial mapping. This conceptual mapping can be automatically activated when we reason about the succession of events (Boroditsky, 2000; Boroditsky & Ramscar, 2002; Miles et al. 2010). Nevertheless, time is represented in our culture also as moving along a lateral time-line, so that the past events are on the left and the future events on the right. We can experience it by looking at a calendar or a comic book. But this is how time flows in graphic representation of our western culture: it is enough to look at a calendar in Casablanca to discover that time sometimes flows from right to left. This may seem like nothing shocking. However, it might be interesting consider that when people think about time, they can do that on the basis of an implicit conceptual mapping according to which time flows along a lateral axis, whose direction varies across cultures.

Tversky, Kugelmass, & Winter (1991) asked children and adults to place stickers on a page to indicate where *breakfast* and *dinner* should appear relative to the *lunch* sticker, in the middle of the page. Whereas English speakers placed breakfast on the left and dinner on the right of lunch, Arabic speakers preferred the opposite arrangement. Fuhrman and Boroditsky (2007) showed a similar pattern in a reaction time (RT) task with adults. Ouellet, et al. (in press) asked Spanish and Hebrew speakers to judge auditorily presented words referring to the past or future with either their left or right hand, and found a similar reversal of the lateral space-time mapping across groups.

These experimental data reflect patterns that can be found in spontaneous behavior, as well. When English speakers produce co-speech gestures they tend to use the lateral axis for time, much more often than the sagittal axis (Casasanto, 2009a; Cooperrider & Nunez, 2009). Earlier times are on the left and later times on the right of body-centered space. Preliminary data suggests that Spanish speakers' gestures follow a similar pattern, but Arabic speakers' spontaneous gestures show the reverse mapping (Romàn, Casasanto, Jasmin, & Santiago, in prep). These studies are all evidence that our metaphorical concept of time, although based in part (and maybe originally) on sensorimotor experience, can be shaped by external representations of time that spontaneously arise in different culture. In a few words, people in different cultures represent time in a different way, also at automatic, unconscious levels of thought (and not just when they are looking at a calendar!) This is indeed a good example of cultural relativity for the space-time conceptual mapping (see Chapter 10).

Interestingly, this particular mental metaphor, which seems well established in mind, it is not represented in language. No known spoken language uses the lateral (left-right) axis to talk about time conventionally, and invented left-right metaphors for time sound nonsensical: Monday comes *before* Tuesday, not *to the left of Tuesday* (Cienki, 1998). Although the way we speak probably has nothing to do with the construction of the lateral temporal axis, a central role might be played by the way we write. Across cultures, the direction in which time flows along the mental timeline varies predictably with the orthography of the dominant language: time flows rightward in cultures whose literate members use a left-to-right orthography and leftward in cultures that use a right-to-left orthography. Yet, despite this clear correlation, it is not known to what extent reading and writing direction is a *cause* or an *effect* of cross- cultural variation in implicit space-time mappings.

We set up an experimental intervention to determine whether experience with reading a left-to-right or right-to-left orthography is sufficient to determine the direction of people’s implicit associations from space to time. Native Dutch speakers were assigned to perform one of two space-time congruity tasks. In one task (Experiment 1), participants saw past-oriented phrases (e.g. *a year earlier*) and future-oriented phrases (e.g. *a decade later*) appear on the screen one at a time, in standard Dutch orthography. As soon as each phrase appeared, they pressed a button (located on the left or right of a keyboard) to indicate the temporal reference of the phrase (past or future). Each participant performed two blocks: in one block the left-right key mapping required responses that were congruent with a left-to-right flow of time, and in the other responses were congruent with a right-to-left mapping. We predicted that, on average, participants would show an RT advantage for responses consistent with standard Dutch orthography (left-to-right).

The other task (Experiment 2) was identical to the first, with one exception: all instructions and stimuli were presented in mirror-reversed text. Reading requires scanning the page in a particular direction: normally for Dutch speakers reading each line of a text requires moving the eyes gradually from the left to the right side of the page or the computer screen. As such, moving rightward in space is tightly coupled with ‘moving’ later in time. We reasoned that if the habit of reading from left-to-right contributes to an implicit left-to-right mapping of time in readers’ minds, then practice reading in the opposite direction should weaken and eventually reverse this mapping.

Experiment 1 showed that, when exposed to temporal phrases presented in standard left-to right orthography, Dutch speakers implicitly associated earlier time intervals with leftward movements and later time intervals with rightward movements, consistent with previous findings in members of other cultures that use the Roman writing system.

However, when exposed to several minutes of mirror- reversed writing, Dutch participants began to show space-time congruity effects that revealed a reversal of their normally dominant implicit space-time mapping. By the second time they were judging each of the 48 temporal phrases (Block 2 of Experiment 2), participants were faster to make responses when key presses associated earlier events with *rightward* movements and later events with *leftward* movements -- a pattern observed previously in speakers of Hebrew, which is written from right to left.

These results show that experience reading a right-to-left orthography (which requires the reader to 'progress' leftward across the screen with his/her eyes) were sufficient to reverse the flow of time in the reader's mind, at least transiently. Therefore, not only is the temporal space-time mapping in the human mind subject to cross-cultural variation, but also the aspects that vary according to specific cultural patterns (at least in this case), can be easily modulated via experience. How best to characterize the learning mechanisms that afford this representational plasticity remains another open question.

Among the cultural aspects that might influence the way we think about time in terms of space, a significant one is of course language. In Chapter 11 we have shown how people that use different metaphors to talk about time, in their natural languages, also think about time differently. And this is true also if speakers of different languages have more or less the same sensorimotor experience of the world, at least considering the experience of moving through space and through (literal) time. As in the case of cultural relativity presented above, in these cases of linguistic relativity the space-time mapping was modulated just by the use of specific metaphors in their languages. For example, Mandarin speakers who talk about time in terms of *up* (before) and *down* (after), are more likely to activate an implicit vertical space-time mapping than English speakers, who do not have these kind of metaphors in their language. Moreover, training experiments similar to the one we performed in Chapter 10, where English speakers were trained (in English) to use metaphorical expressions like those used in Mandarin, were likely to automatically activate an 'up-down' implicit mapping (during temporal reasoning), like their Chinese counterparts. These results, once again, speak for the considerable plasticity of these metaphorical representations, but they also allow us to posit a causal role for language in shaping the way we think about time.

Nevertheless, even if speakers of different languages use different metaphors, the habit of talking (and thinking) about time in terms of space seems to be ubiquitous (Haspelmath, 1997). This fact supports the claim according to which the conceptual space-time mapping is universal, because it is grounded on sensorimotor experiences that are the same for each human being (Lakoff & Johnson, 1999).

Recently, Chris Sinha, Vera da Silva Sinha, Jörg Zinken and Wany Sampaio (SSZS) have challenged this conclusion on the basis of their work with a small population who lives in the Brazilian Amazon rainforest: the Amondawa. On the basis of both observational data and structured field linguistic tasks, SSZS have shown that a linguistic space-time mapping at the constructional level is not a feature of the Amondawa language, and is not employed by Amondawa speakers (when speaking Amondawa). Amondawa does not recruit its extensive inventory of terms and constructions for spatial motion and location to express temporal relations, and metaphorical constructions like the Ego-moving (We are approaching the deadline) and Time-moving (The deadline is approaching us)[141] which have been claimed to be universal (Lakoff & Johnson, 1999) seem to be absent.

I contributed to the study of the Amondawa language collecting data about the way Amondawa speakers talk about duration. Preliminary analyses on this data are reported in Chapter 11.

SSZS have claimed that this lack of linguistic metaphors corresponds to a lack of conceptual metaphors. Amondawa speakers, although they have the cognitive capacity to represent time as a space 'in posse', they do not do that. SSZS claimed that in order to construct a space-time conceptual mapping it is necessary, before, to have a representation of time appropriate to 'receive' this mapping from spatial conceptual structure. In other words, the Target concept of time, which for Lakoff & Johnson is the experience-based and universal 'literal time', is instead a cultural construction that might be missing in certain populations.

I think that SSZS's theory needs to be tested on the basis of nonlinguistic data. However, the question of whether a non-spatialized concept of time exists which is the Target time of the space-time metaphorical mapping, and which are its characteristics, is still an open question.

Although we were not be able to answer this question, at the very end of this work we tried to demonstrate that such a primary concept of time cannot be the 'literal time' as it is described by Lakoff & Johnson. We have done that following the Piagetian theory of the construction of the concept of time in the child (Piaget, 1969), and on the

[141] See Chapter 5

basis of experiments in developmental psychology as well as the epistemological and philosophical analysis carried on in the first part of this thesis (Chapters 2, 3 and 4).

Ultimately, we think that the so-called 'literal time' described by Lakoff and Johnson can be neither the basic and universal experience of time, nor the non-spatialized time which is the target of the metaphorical mapping. Eventually, Lakoff & Johnson's idea of 'literal time' resorts to the metaphor of the internal clock and its understanding of time as a sensory process - a theory that we tried to falsify in the first section of this work.

If our experience of time is in large part fruit of a metaphor from space, as we think it is, then a non-metaphorical, non spatialized time that receives the mapping seems to be needed. To explain what is this primary experience of time, is the challenge with which philosophers and psychologists have been engaged for years. And it is still an open question.

On the other hand, as suggested by Wittgenstein, it might be true that time can never be conceived of in its own terms. Not only in physical terms (i.e. the essence of time itself) but also in its psychological terms (i.e. the basic experience of duration). Contrary to the well-known opinion of Bergson, there might be not a psychological experience of duration which is the 'real time'; rather, time  is always conceived in terms of something else.

As Richard Feynman pointed out, time is what happens when nothing else does. But it seems there is always something else going on.

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