Time and Space

Are of the Same Stuff

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December 2011

Résumé

Nous proposons de penser ensemble les concepts d'espace et de temps : ils concernent les mêmes degrés de liberté des éléments du monde et fonctionnent toujours en tandem. Leurs fondements doivent être discutés, non dans une pensée de la substance (chacun est défini par une série de caractères qui lui sont propres) mais dans une pensée de la relation (chacun se définit en opposition à l'autre). Nous opposons des relations spatiales à des relations temporelles, ou encore des relations d'immobilité à des relations de mobilité relative. La décision de la frontière entre ces deux ensembles de relations est sujette à arbitraire : nous avons une grande flexibilité dans les définitions associées des paramètres d'espace et de temps ; elle ne fait pas non plus l'économie de difficultés conceptuelles ou logiques semblables à celles rencontrées dans la mécanique quantique. Il faut revoir dans cette perspective autant le concept de temps que celui d'espace : le temps ne coule pas, il est changement de relation, il est mouvement ; l'espace est abstrait à partir de relations constantes ou morceaux constants de mouvement. Les mouvements relatifs qui expriment ces relations, changeantes ou non, contiennent toujours un aspect spatial et un aspect temporel, comme pile et face de la même réalité. Nous proposons de voir plus généralement dans toute relation un aspect spatial (l'écart qui sépare les deux termes de la relation) et un aspect temporel (le parcours du chemin qui les relie). Sur cette base, nous proposons un programme de recherche pour reprendre un certain nombre de problèmes fondamentaux de la physique contemporaine, ainsi que des pistes pour reprendre ce que nous disons du temps et de l'espace dans les sciences humaines et sociales, la culture, et jusque dans la vie quotidienne.

Mots clés : temps ; espace ; mouvement ; pensée de la relation ; pensée de la substance ; théorie de la relativité ; incertitude ; incomplétude ; espace-temps ; paramètre temporel tri-dimensionnel

Abstract

We propose to consider the concepts of time and space together. Both of these involve the same degrees of freedom of worldly elements and always work in tandem. In discussing their fundamental points, we need to use relation-based thinking, where each is defined in contrast to the other, instead of substance-based thinking, where each is defined by its own set of characteristics. We contrast spatial relations with temporal relations, or relative mobility with relative immobility. The boundary between the two is decided arbitrarily (there is a great deal of flexibility in definitions of associated time and space parameters), but such a decision runs into logical and conceptual obstacles similar to those encountered in quantum mechanics. Given this prospect, we need to revise the concepts of both time and space. Time does not flow, it is change in relation, it is movement; space is abstracted from constant relations or constant slices of movement. The relative movements that express these relations (changing or unchanging) always take both a spatial and a temporal aspect, like two sides of the same reality. More generally, we suggest seeing a spatial aspect (the distance separating the two terms of the relation) and a temporal aspect (travel along the path linking them) in every relation. On this basis, we propose a research program to examine a number of fundamental problems of contemporary physics and avenues for rethinking how we express time and space in the behavioral and social sciences, in culture, and even in everyday life.

Key words: time; space; movement; substance-based thinking; relation-based thinking; relativity theory; uncertainty; incompleteness; space-time; three-dimensional time parameter

1. **Introduction**

In this work, we would like to discuss the concepts of time and space using relation-based thinking, which considers each concept in relation to the other, rather than the more usual substance-based thinking. Our understanding being that time and space always work in tandem, we are led to reconsider the meaning of both. The meaning of time: it doesn't flow anywhere; it is not a property of any point; it is relation; it is change of relation between the material points in space; it is movement. The meaning of space: it depends on presumably invariable relations between its constituent points that are expressed by constant fractions of movements, referring to the time they take. If the thought given to the time concept takes up more room here, as is often the case, it still concerns space, which must also be reexamined in terms of its connection with time. These ideas lead us to delve further into physics and into a more mundane understanding of time and space. In this article, we discuss relation-based thinking as an indispensible aspect of the argument; insofar as we propose generalization (every relation contains both a temporal and a spatial aspect), it is also a key aspect of our study.

The article is organized as follows: in section 2, we briefly describe the two modes of thinking (substance / relation). In section 3, we bring into contrast the "spatial" relations between the worldly elements on which we construct space and the "temporal" relations on which we construct time. In section 4, we turn our attention to the characteristics of relation-based thinking or more specifically, movement-based thinking, which reveal a certain number of conceptual and logical limits (incompleteness, uncertainties, recursive loops, contradictions). In section 5, we present a very general abstract framework for the stages and conditions of relation-based thinking during our discussion of time and space. The next two sections treat the application to physics (section 6), by raising a few questions that can be rephrased in the vision presented, and to culture in the larger sense (section 7), by looking at certain time aporias and our proposed solution. In section 8, we conclude on the question posed in the article's title: Can we think time and space "together"? Our bibliography covers a very broad range of subjects and is thus necessarily limited.

2. Two modes of thinking

How do we imagine the world, and how do we express it? More often than not, we act as though we could see the world from the outside and link the elements we can pick out with words from an independent knowledge system hovering over the world like a sky of Platonic ideas, a world of eternal principles. For example, to imagine or say the word "horse", we link it spontaneously with a definition of horse (an animal with specific characteristics from a pool of seemingly predetermined characteristics), just as we do with a dictionary, even if it means supplementing the initial definition with others. In this case, there is no need to compare and contrast the worldly elements, each one is seen as and for itself. To get back to our example, we don't need to imagine a cow or pig "at the same time" to express what the horse is not. We call this "substance-based" thinking. The characteristics of such thinking have been explained in various terms by many authors including decisive contributions from Plato and Aristotle [Aristotle 4th century BC] or, closer to our times, from Descartes [Descartes 1644], Newton [Newton 1687], and Kant [Kant 1781].

This type of thinking, based on an apparent nature or substance that is inherent to worldly elements has its limits, especially nowadays. In parallel with the dominant mode of thinking, another one that was first stated by Heraclitus [4th century B.C.] and the pre-Socratic thinkers developed over the centuries. Even today, without trying for exhaustiveness or subtle shades of meaning, one can find influences in the works of researchers like Edgar Morin [Morin 1986], [Morin 2005]. Contemporary authors like François Jullien (in particular on Chinese thinking, e.g. [Jullien 1993] and [Jullien 2006]) and Michel Bitbol [Bitbol 2010] have started studying and writing about it again. This second mode of thinking stresses that we are not outside the world, but within it: we only see relations or contrasts between the worldly elements. To imagine a horse, we make (or have already made) a series of comparisons between different animals and then identify what makes the horse different from other animals. Expressing what a horse is boils down to making a list of all the animals it is not. This implies that by thinking about the horse, in a way we are also thinking about all the other animals living or dead (and beyond, about all inanimate matter), dividing them up and separating them out to define a horse. This is also how scientific thinking proceeds these days, albeit more rigorously, to place the horse in a phylogenetic classification system (how many characteristics separate it from any other animal?) as opposed to the earlier evolutionary tree approach (is such or such characteristic inherent in a horse?). We call this type of thinking “relation-based”. In the past, a number of authors including Montaigne [Montaigne 1580] and Pascal [Pascal 1670]) insisted, if not on the relation, at least on the need to build our knowledge through dualities or even contradictions, and to match opposites.

Even if this relational intelligence is not sufficiently put forward in contemporary thinking, we believe that this is really how we think or begin to think, including for fundamental categories such as time and space – and that brings us back to the subject of this article. In the first conception just mentioned, we believe that we link time and space (presumably revealed by experience) to a series of qualifiers enabling them to be described independently of each other. There is then no need to “think” space to express time, and vice versa.

In this article, we would like to develop the viewpoint that relation-based thinking must be used to discuss concepts of time and space, specifically in relation to each other: to imagine space, we need to contrast it with time. Time and space are imagined together, in contrast. This will be a way of recognizing that if we associate time and space so often to describe the framework for the phenomena presented to us, it is not at all a coincidence: they are two sides of the same coin, two faces of the same reality. By expressing time and space in this way, we will also see how relation-based thinking operates. A number of scientific authors have discussed the concepts of time and space in terms of relation (see for example [Mach 1904], [Whitehead 1922], [Barbour 1982], [Earman 1990], [Rössler 1998], and [Assis 1999]), but they take each concept into consideration separately without noting, as we do here, that the *same* relations are at work for both, linking them inextricably.

3. Spatial relations, temporal relations

Let’s turn now to how relation-based thinking is used to construct concepts of time and space. Our world is given to us once, and not three times as it is usually understood when taken to the limit (once with space alone, once with time alone, and once with both time and space): There is no label on what time is, nor is there one on what space is. In our understanding, time and space are not inherently real, they are concepts abstracted from what we designate as relations between worldly elements. We will divide these relations into spatial relations and temporal relations. When discussing relation-based thinking, “relations” is used in the second degree, as opposed to what in the first degree we also call *relations*, both spatial and temporal;

the context of word use will avoid ambiguity. We do not enter into the recursivity problems that crop up at this point. How can we understand the contrast, or the separation between spatial and temporal relations? We have examined that in a number of works, e.g. [Guy 2004], which we can briefly touch on. There are several possible explanations. We can take a pragmatic approach and see how, for thousands of years, we have been effectively constructing the rulers and spatial frames of reference that serve to mark out our territories and the time markers that serve to arrange and organize events. For space, we place boundary markers in the earth or refer to rulers, and we use triangulation to create maps. For time, we identify the different positions of the sun relative to the earth, or the different positions of a marker coupled to a more or less sophisticated mechanical system or, by extension, we observe the relative positions of a photon moving inside in a box we call an atomic clock; we match up our historical events with these positions and, out of the many points that we might determine to be in motion, choose one that can be agreed upon.

We consider that in doing these things, we are already using relation- or opposition-based thinking, perhaps without even being aware of it. In fact, we are creating a separation in our world between a set of relatively stable, immobile or invariant positional points (e.g. the boundary markers placed on mountains or the endpoints of a ruler) and a point or set of points that move relative to the first points, e.g. the sun, the hands of a clock, the grains of sand in an hourglass, photons, or even waves in the ocean or clouds. This opposition helps us define both sets. We express nothing "positive" about either of the sets in doing so, but merely a relative point of view: We "immobilize" the one relative to the other, which is declared to be in motion, and more specifically in motion at a constant velocity within a clock (we have no fundamental certainty of the real immobility of one or, equivalently, of the constant mobility of the other, as a function of the words that might be assigned outside the world according to criteria, e.g. rulers and clocks, that are independent of the world). It would be better to just say that the first points do not move "much" relative to the second ones. This opposition-based construction is arbitrary to a certain degree, as simple thought experiments show us [Guy 2004]. If we lived a lot longer and much more slowly, the mountains on which we placed our boundary markers would move like waves in the ocean. We could use them to define time, and what served to define space would then serve to define time. But we can also imagine that if we lived a shorter time at a more rapid pace, the grains of sand in the hourglass would not budge throughout our entire lives. We could use them to pinpoint space, and what served to define time would also serve to define space. Some might say "that is a fine allegory, but sooner or later we will be able to stop somewhere and say ‘here is space, here is time’.” Well, in point of fact, no! In this continuum of relative motion, one cannot come to an absolute and final stop; there is no preexisting break, there are no tools outside the world to give us access to a time and space that would be fundamentally separate from each other. *It is not a problem of subjective perception that could be resolved with more finely tuned instruments: neither the observer nor the measuring tools, all of which are within the world, can stop at an absolute boundary*. The constant mobility and immobility are considered together; we are in a self-referential situation that leads to undecidable proposals. We make a “temporary” break between time and space by stopping a regression that would take us to infinity, thereby giving access to a more or less accurate description of the world. This is expressed in the Lorenz transformations used in the special theory of relativity. Our freedom to choose comes into play in this break; we can speak of “arbitrary choices”, i.e. choices left to our free will. The current physical construct is light based, as in the decision c = constant (c being the speed of light). But among others, we could also create a physical construct where the velocity of the sun’s visible motion around the Earth (or more accurately, the sidereal rotation velocity) is constant, as was done in the past. We could ponder these conflicting physical constructs from the outside: even though some of them might be more difficult to implement, each one is internally coherent.

4. Motion- and relation-based thinking

To recapitulate, time and space are constructed in opposition to each other within a set of relative movements and both involve the same degrees of freedom of worldly elements: space (or spatial relations) is (are) constructed from “stopped” or infinitely slow *movements* in relation to other movements that allow us to construct time (temporal relations). They are two sides of the same coin. The time/space duality is not the result of a duality of substances, but of the multiplicity of worldly elements and of the potential division of their relations into two or more groups. In the process, we make *movement* primary, enabling space (amplitude of movement) and time (movement process) to be expressed simultaneously. We also associate one or more movements with each perceptible slice of reality. Some authors have stressed the specific characteristics of movement, e.g. [Chatelet 1993], [Maldiney 2001], and [Webb 2006], but without re-examining as we do the associated meanings of time and space concepts (see [Guy 2004, 2010e]). The re-examination concerns space as much as time, and also the movement itself, which we consider independently of its velocity, since velocity results from the comparison of two movements.

The conception of space must be revisited in relation to movement. Connecting the points that constitute space gives space its meaning and reveals the role of displacement. What meaning would space have as a set of unconnected points? The position of a point reflects its displacement away from an origin. The link between space and movement (displacement), and *through them, time*, takes us to biology and the cognitive sciences, where modes of apprehending space through movement are studied ([Alegria 1983], [Imbert 1983], [Moraïs 1983], [Ninio 1983], [Berthoz 1997]). In his work, Berthoz stresses that, generally speaking, perception and knowledge through perception are closely linked to action and movement. He summarizes this by saying that perception is a simulated action, and that the brain is not a representational organ, but a biological simulator: "the most sophisticated properties of human thought and sensibility are dynamic processes". In this context, the brain's construction of space is linked to the subject's own exploration of the world, and the link makes practical use of sensory receptors in the muscles, the inner ear and all over the body. This set of receptors defines what Alain Berthoz calls "the sense of movement". One might say that space as we construct it in our brain is an *internal simulation of movement*; it isn't explicitly coded as "space", but appears as the node for the set of trajectories that passes through it. Poincaré [Poincaré 1902] himself saw this link between space and movement. He asked the initial question of why we need to construct a geometrical space: we do so insofar as a geometrical space is useful in representing our movements and the conditions of our action. We do not represent bodies in geometrical space, but we reason about bodies as though they were located in a geometrical space. Geometry is the description of phenomena that we call displacements, i.e. external changes, which are compensated for by the internal changes in our bodies that can be measured by vestibular receptors. This geometry is based on solid bodies: Poincaré points out that if no solid bodies existed in nature, there would be no geometry. By linking the work of Berthoz to that of Poincaré, we draw attention to a chain that goes from action to geometrical space, via cerebral representations. For Teissier [Teissier 2009], the mathematical real line (meaning real numbers) cannot be separated from its cognitive construction: we imagine that we progress along it at constant velocity, *so it is invisibly parameterized by time*. Returning to our point, we will say that space as an internal simulation of movement is inextricably linked to time. Time itself is another aspect of movement, with movement taken in a very general sense beyond that of the subject who experimented first with it. It is movement in the sense where we call geometry a science of displacements. It could be worthwhile to delve further into such a review of how we understand space.

We also need to reconsider the meaning of time. As already mentioned, time doesn't flow anywhere, it is not the property of any point, it is relation, it is change of relation in space, it is movement (this brings to mind Piaget's work [Piaget 1967] on constructing the notion of time in small children).

From this point forward, we will refrain from speaking of time without also speaking of space, and vice versa.

Characteristics of relation-based thinking

The statement "time is defined by movement" (space is defined by movement) deserves discussion, however. Because we are faced with a contradiction: could time be defined both before and after the movement? (could space be defined both before and after the movement?). How can one define the movement without first defining space as well as time? This type of question leads to the limits of logic, opening up broader avenues of thinking. The intellectual structure around the theory of relativity is comparable to that of quantum mechanics, which has been the subject of much discussion in that respect, but not with respect to the discussion of time and space concepts. Typical features of this structure, some of which have already been raised herein [Guy 2010a], are:

- *uncertainty content:* we are not sure that words and things strictly correspond; nor are we sure of the numerical values we assign to physical quantities. In other words, we are not completely sure of the state of mobility or immobility of any one material point, and we are not sure of the numerical value assigned to its velocity (we can also apply uncertainty relations to this situation, see [Guy 2004]);
- *incompleteness:* the constructed reasoning leaves things out and does not stand on its own, there are
- *arbitrary choices*, i.e. subject to free will and not strictly imposed by reality, originating outside the initial reasoning (incompleteness, see [Léonhardt 2008]); we choose to say that the

velocity of light is constant and we then take up that choice in our measurements and in running our equations. These choices can lead to

- *potentially contradictory thinking patterns,* i.e. we can have a number of physical constructs based on different choices of the phenomenon determined to be of constant speed. This confronts us with

- *recursive situations* where words are used to define each other, and which can only be resolved by showing – by *making do* with just showing – something of “reality”, without being certain of its equivalence with words that would be defined outside the world. We do that with the idea that the phenomenon (propagation of light) serves as a “constant” base.

5. Constructing relation-based thinking

The conditions for relation-based thinking

Constructing the concepts of time and space as we have done reveals a series of conditions which can be used as a basis for relation-based thinking, like elementary steps in the process. We can see it as a set of basic intellectual operations or a general abstract structure, for imagining the world as well as time and space concepts ([Guy 2010b]; see also [Dujardin 2009]).

- *The empty stage* – Relation-based thinking implicitly assumes that there is an empty stage where it is possible to consider worldly elements and links being established or broken between them. That is the condition for creating such links. We could call this void “space”, but we distinguish between the void and space, with space depending on what we have called spatial relations. This common pool also serves to define temporal relations (and time) in contrast to spatial relations. From other points of view, the void links up with things like the indefinable, the context of incompleteness, the being, the hidden reality (in contrast to our constructs). This void is the pool from which we pick out the worldly elements we want to distinguish, and to examine the relations thereof (the void is, once again, absence of relation).

- *Separation* – On our empty stage, we classify worldly elements into groups (e.g. immobile points in the solids) by placing a boundary or break that separates them from one or more other classes (mobile points). Basically, rather than use an identity axiom to define A, we need to say “A is not non-A” by contrasting it with B, C, D, etc.

- *Equivalence relations* – When we do this, we affirm a certain equivalence (cf. equivalence relations in mathematics) between the points in a specific class. The solid is seen and considered as an integral whole. This is also the case for spatial thinking, which is the result of a comprehensive view of a group of points.

- *The need to pose an absolute* (at least temporarily) – The limit of relation-based thinking is that it leads to endless regressions. How can one determine whether or not a point moves with respect to another, or if it rates being associated with other points in a solid, or to be included in a set of "spatial relations" (i.e., invariable)? Or more generally, how to determine the distance between one specific point and another in order to decide whether it belongs to the group or not? In order to assess the invariance of the relations between two points, one has to be sure of the constant distance between them. For that, one must use a constant-speed movement in the reference phenomenon. But how to assess that movement without comparing it to another movement (and so on)? To stop these regressions and "stabilize" this type of relation-based thinking, we can only assign, at least temporarily, an absolute (representative and invariant) characteristic to any one chosen worldly phenomenon. We say: "The phenomenon we are showing you is described by a propagation at *c=constant* velocity with respect to these rulers, which we designate as invariable. We take this choice into account in making our proposals consistent and experimenting until it is necessary to make a more suitable choice." In a sense, it is a return to substance-based thinking, but with the perception of its own insubstantiality, even if that is necessary for thinking. For the benchmark phenomenon, we make do with the statement "A is A" rather than "A is not non-A". This operation does not involve substance-based thinking in the usual sense insofar as it works as much by designating a specific phenomenon in specific circumstances ("see which benchmark I use in such-and-such experiment"); it is not the same as assigning a chosen (absolute and general) characteristic to a substantial property of nature. The symmetry of the relation between two elements A and B also requires postulating an absolute that is common to both terms of the relation. Behind that is the question of the right interpretation (choice of the absolute) and the authority needed to assert it. Here, you can consult Ricoeur's research [Ricoeur 1969] on hermeneutics, which needs to be extended to the field of physics. The conditions treated in this section help to explain the characteristics of relation-based thinking (section 4).

The insubstantiality of our absolute is both unusual and paradoxical: we are never sure whether the worldly material points which we have set in our construct move slightly relative to one another or not. One could even imagine that they expand, but that the velocity of the relative movements vary proportionately so that there is no observable effect. As Poincaré already noted, our mathematical representations incorporate this uncertainty. Thus, we are led inevitably to think in terms of uncertainty, in the sense that we are not sure of the meaning of the words we use regarding material points (mobility vs. immobility). We act, however, as though this meaning were given by an analysis of criteria that are independent from the world, e.g. we continue to say "light propagates at constant velocity". If we can speak of a link between time and space for any amplitude of reality (i.e. a movement that is established by the constant velocity of the benchmark phenomenon that has been proposed as an absolute), the link itself is ultimately open to question. Note once again that making a benchmark phenomenon absolute is arbitrary. It is based on the objective necessity to give the chosen object that status, and not on any immanent property of the object. In other words, assigning an absolute character is always subject to change; the absolute is relative to the constructed interpretative model. In quantum mechanics, the uncertainty about the position of the material point – for which the localization spreads out like the wave function – adds to, or rather, connects with the other uncertainties. (Further on, we discuss the link thus established between the special theory of relativity and quantum mechanics.) Uncertainty, changeability, and the "relative" character of the absolute are notions that are all on the same level for our purposes; accepting that is a crucial part of the intellectual process.

Time and space in all relations

We can go even further and generalize the concepts of time and space using the concepts of relation and movement. Whenever there is a relation, we say that there is space, in the amplitude of the relation and in the distance implied by the relation. Whenever there is a relation, we say that there is time, in the expression of the relation and in the travel along the path of the link connecting the two terms. Every relation inextricably separates (space) and connects (time). Without eluding the previously mentioned conceptual and logical obstacles, we need to use these propositions to elucidate a number of issues with regard to culture, the social sciences and the natural sciences. We specifically need to incorporate a temporal aspect into our different conceptual constructs, e.g. the time for biological evolution that expresses the hidden link between animals that we classify by relationships. In substance-based thinking, however, there is no time factor and the worldly element is compared instantly without reference to time with the word that designates it in the knowledge system (or the "Logos"). From this angle, we must reconsider the way we conceptualize, construct and organize our knowledge.

6. Time in physics

Two observations

To get back to contemporary physics, we can make two observations: 1) the issue of time has not been solved yet. It can be avoided in advance by choosing a parameter t in addition to and beside x, y and z. Any discussion on its construction is disregarded in advance. New theories that take many dimensions of space into consideration (different types of string theory) generally do not investigate the time issue. 2) There is much discussion around the problems with physics or with existing theories (see e.g. [Selleri 1998], [Smolin 2007]). The literature on the subject is so vast that we cannot examine all of the debates here. None of these voices contests in essence the existence of time and its current representation in physics. Given these two observations and the preceding discussion, we believe that *in-depth conceptual thinking on time and its links to space is essential for any progress in physics*. Besides the problems for which we have proposed solutions or partial solutions [Guy 2004], a clearer understanding of time and its connections with space could have a greater import by enabling discussion of new issues in physics.

Time in quantum mechanics

Some authors, like Rovelli [Rovelli 1990] [Rovelli 1991], demonstrate that it is possible to dispense with the time parameter in the formalism of quantum mechanics. Others emphasize the conflict between relativity's time and some quantum mechanics experiments, giving rise to doubts about the existence of time "at a certain scale". Couldn't these problems be avoided by noting that time exists at no scale and that it is only a marker? It is ultimately absurd to want to assign individual particles their own "proper" time, when time is relation. Discarding the concept of proper time and pointing out the conventional nature of time eliminates the need to raise the issue of the scale at which (microscopic or macroscopic) we can or cannot associate a temporal parameter with the equations of quantum mechanics. In the same way, Langevin's twin paradox becomes clearer: the age difference corresponds to a different point of view with respect to a mobile frame of reference and not to an actual “proper” age without meaning. Interpreting Lorenz relations as uncertainty relations [Guy 2004], can also somewhat attenuate the conflict between relativity and quantum mechanics. The uncertainty we see there is about the mobility/immobility properties of the material frames of reference that we must use as a basis to identify our positions and times. They can be expressed by a small unknown velocity that governs the displacement between two geometric frames of reference on which we formulate the Lorenz transformations.

Light propagation velocity

Other issues are raised about the constancy of light velocity in time or in the different directions of space (e.g. the question of light propagation isotropy [Nodland and Ralston 1997]), or the existence of superluminal velocities. You can address these with a caveat: in principle, the choices are conventional ones, but, while it is essential to make them and take them into account afterwards, it could become necessary to make other choices as a function of the situation. Nature does not impose its laws strictly. We have a certain latitude in formulating them, and in the present context, it may be understood that we are skeptical about some physical theories that postulate parallel universes governed by other laws, as if these laws were prescribed independently of human choices. Poincaré had already promoted theoretical pluralism [Poincaré 1902], [Poincaré 1905] (see also [Greenberg 1997], [Mizony 2010]), which we revisit here.

The irreversibility of time

On irreversibility, we can say that the main problem with time is not whether or not it is irreversible, but whether or not it exists. Neither time nor space exists alone; both are constructed from the world; they are relations. It is because time is associated with one or more movements in space (rather than being an abstract flow independent of space) in contrast to stable spatial relations that we can oppose its irreversibility to the reversibility of spatial relations. The reversibility/irreversibility contrast is also based on this opposition, understood simply to be the possibility or impossibility for some worldly particles to go backwards with respect to others that serve as spatial frames of reference for a potential backtrack. The uncertainty about the definition of the spatial and temporal parameters places fundamental limitations on the possibility of discussing such a backtrack. Reversibility and irreversibility are considered together, like time and space, and their limit can only be approximate. The very laws of mechanics are reversible only insofar as it is possible to define a fixed spatial frame of reference, and because in practical terms we define frames of reference based on material points, this is always subject to approximation. In this respect, one might just as well speak of the irreversibility of space (cf. [Guy 2004]), or of the irreversibility of space-time as it is understood in the present article. This basic irreversibility, conceptual or ontological, links up with the practical irreversibility that is already understood for multiple particle systems in which the time arrow is found by factoring in the effects of uncertainties on the initial conditions and the effects of various types of perturbations on the trajectories (see the analysis in [Guy 2008]).

7. Time in culture

With respect to cultural time, we note that just as space is multiple (multiplicity of places), it is possible to observe *multiple relations* between worldly elements, and *multiple times* in focusing on any one part of the world or any one movement ([Pomian 1984] also talks about this multiplicity). However, above and beyond these multiple times, we also had to define a single time for our mutual communication and to link all the other times. *This single time is physical time* (usual, or universal time), which we mentioned earlier. *It is simply a point of reference outside the other things*. It basically has no significance for the way any one part of the world functions.

Understanding that gives us a position from which to address the problems with time that continue to crop up in philosophy, the social sciences, and culture. Let’s take a look, for example, at some well-known time aporias (of course, we will also have to talk about spatial aporias, see [Guy 2004]), keeping in mind an age-old question: how can time exist, given that it consists of 1) the past, which no longer exists, 2) the future, which doesn’t yet exist, and 3) the present, which is a non-existence sandwiched between two non-existences? Associating time and space provides some answers [Guy 2010b], but one must go back to the source, which is movement. As we have noted, by focusing on any one movement we oppose what is spatial (very slow movements) and what is temporal (“sensitive” movements). Thus defined, however, time remains “alongside” space (using the most ordinary meaning of “alongside”). In a way, a slice of solid that is stable is spared by time, which flows “elsewhere”. The past/present/future grammatical tenses concern neither this mobile temporal slice that is outside stable things, nor the universal time that is only a marker, but it does concern the space-time set within the multiple spatial and temporal relations. Following in the footsteps of Einstein [Einstein 1905], we could already link the categories of time to the indivisible space-time association. The link reflects the fact that language concerns the way the world functions as a whole and not any one slice that is more or less artificially separated (time, with respect to space). So when we speak of the present, we are speaking both of the cloud that forms and dissipates, with reference to time expressing change, and of the motionless mountain that has been there for thousands of years, with reference to space. It would be absurd to say that the mountain disappears constantly into the past only to reappear in the present. It is temporarily outside of time. We could speak of "present past" to designate this spatial part (not purely temporal) of grammatical time. The mountain is also a present of the future (a present future, for at least a near future). That is the full meaning of its presence. What is really past, the "past past", is the moment that counts as the fluctuating boundary (moment of aggregation) when the mountain appeared, even if we must consider long durations for that. The same is true for the truth of the future, the "future future", which will or will not reveal disintegration of the mountain and a new recombining of its elements. By adding two temporal terms to designate a single experience (present past, future future), we can introduce nuances into the mixed spatial/temporal properties of the grammatical categories (for the issue of time, space and language, see [David 2004], [Asic 2004], [Hagège 2009]). Another way of describing the properties of the present would be to assess the proportions of what changes in the environment of the subject, or in what the subject perceives: a present that is 90% spatial and 10% temporal, to indicate that the proportion of what changes around him (or what the subject perceives or chooses to perceive as changing) is 10%. It can be postulated that the "thickness" of that present – its duration – is a function of the percentage, if one assumes implicitly that this percentage cannot vary too rapidly: a present that is 90% temporal, which would be chaos, is more fleeting than a present which is 10% temporal, more like the immobility of a desert. A number of definitions of the past/present/future categories can coexist, each one linked to a class of movements or changes identified in the subject's environment: there is no single time that permeates everything. Priority can be given to several, or to a single one, e.g. the one based on a specific physical phenomenon that allows extensive communication. Compared to that, whatever is not linked to changes can be spatialized. From his specific location, each subject experiments with a certain distribution between the different modalities of his own time. This will take the form of proportions between what he subjectively assigns to the past/present/future grammatical tenses. The effect of signals and material movement between the different locations of the subjects will act as a connection to objectively link up the temporal “magnitudes” associated with individual subjects. This provides a method, based mundanely on the conservation of matter, to link the times of the different subjects and give a quasi-quantitative content to the language proposed for linking the passage of time to the functioning of space: “the future comes from elsewhere”, “the present is pushed to the side”, “the past comes back again”, etc. If the focus is not on the one reference point that establishes the social distinction between past, present and future, it is easy to understand that some say: no future.

The problems raised with time in culture (multiple times and the meaning of the past/present/future tenses) are cleared up by the twofold observation of 1) multiple relations/multiple times and 2) the inevitable choice of a single time. Such is a solution that we suggest for time aporias, based on a new understanding of time and time/space relationships. The solution enables reconciling physical time with time in the humanities. It requires a detailed investigation of the distribution of what goes on around the subject who speaks. It is easy to imagine that this type of rigorous analysis is heavy going, and that everyday expressions necessarily include some logical inconsistencies.

8. Conclusion: thinking time and space together

Can we think about time and space together? Yes, at least momentarily in the mental image that links the two in *movement*; yes, for only an instant in a transient included middle before stopping: we “must pause”, in the words of Aristotle in his *Physics* [Aristotle, 4^{th} Century BC]. Only this pause enables discourse and knowledge, and when the pause is observed, we no longer tolerate contradiction and the middle state. We can draw attention to the conventional and fragile nature – never definitive – of the pause, within an infinite intellectual journey which ceaselessly requires us to rework our formulations. One cannot interpret this pause in opposition to *movement*, either, but rather with it, as a condition for defining it. Does not Chinese thought encourage considering the concepts of dynamic and static together?

While we have used the term *contrast* and similar words as an ingredient of relation-based thinking (contrasting sets of elements, related characteristics, etc.), it would be preferable to speak of *composition*, because the different sets are never imaginable separately. Composition expresses a more "peaceful", symbiotic link than does contrast. The relations themselves compose together: symmetry, equivalence and reversibility compose with dissymmetry, contrast and irreversibility; the void and absence of relation compose with matter and relation; the outside composes with the inside of the boundary, and the designation of the boundary with its crossing; time composes with space, etc. (see [Dujardin et Guy 2011]).

Thinking time and space together may be a temporary stage, but it is a fundamental one that enables an understanding of the genesis of words and of the corresponding concepts; of their limits and the hidden difficulties, from culture and philosophy to physics. The special theory of relativity is there in this association of time, space and movement. The identification that we can make in physics between time and movement does have practical consequences. It leads us to use three coordinates to construct time – not in addition to the spatial coordinates, but as three of them to be added to the coordinates for points in space. These three coordinates correspond to those for a specific point, expressed within the same frame of reference, and for which the movement serves to define time. This gives us a renewed space-time that is more compact than the space-time of standard relativity, which links the measurements of space and time without unifying the concepts. This has a number of consequences for the way formalism operates (formulating general laws of conservation in physics, or Lorentz transformations, or Maxwell's equations; reworking of gravity equations, etc.), as we initially proposed in [Guy 2010c] and [Guy 2010d]. A number of authors have observed that using a three-dimensional time parameter makes physics equations work correctly, or more correctly ([Demers 1975], [Pappas 1978], [Pappas 1979], [Ziino 1979a], [Ziino 1979b], [Tsabary & Censor 2004], [Chen 2005], [Franco 2006], among others). They have not grasped the real point, however, which is that time is not three-dimensional! It is a scalar that we construct to organize our events, but based on a movement that is marked by three coordinates, just like a reference point that moves in space. This reference point can be linked to a celestial object or to a photon in an atomic clock: in this case, the orientation of the device is not arbitrary and the temporal benchmark value incorporates spatial directions invisibly. The use of a three-dimensional temporal parameter is a technical way to resolve the technical problems raised by the special theory of relativity. The approach presented here enhances the theory and paves the way for a conceptual advance that could help to resolve more serious problems, some of which we have mentioned, like the problems between relativity and quantum mechanics. The key to understanding them lies in the great flexibility we have for defining time, space and the related variables, and in the correlative minimizing of the need to concatenate physical processes to maintain a universal time.

This work should be considered as an angle from which to address a number of questions about time and its more or less hidden relationship with space. It lays the groundwork for a program to investigate a number of current fundamental physics issues and touches on some practical aspects of the way we apprehend and discuss time and space. From that respect, it also suggests some avenues for research.

Acknowledgements
I would like to thank everyone who in one way or another have become involved in this undertaking. Thanks also to the researchers with whom I discussed these issues, with a special word for the members of the *Comité Scientifique des Ateliers sur la Contradiction* in Saint-Etienne. A thought for all the authors whose works have inspired my own thinking, and regrets for not being able to mention them all (references do not always mean that I adhere entirely to the opinions of the authors referenced). My thanks to the two anonymous proofreaders (one French speaker and one English speaker) for their encouragement and useful comments for revising the original French article (*Philosophia Scientiae*, 15 (3), 2011, 91-113). And I thank Carolyn McBride Nafziger for her translation from French into English. Any grammatical errors that may have slipped in due to subsequent additions or changes cannot be ascribed to her.

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