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The contribution of relational thinking
and embodied cognition

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Abstract

The basic proposal is presented: *movement precedes both space and time that are derived from it*. As a line of justification, one must guard against two temptations: a) that of believing that reality imposes on us in a univocal way the words to describe it, each one referring to their own qualities of the corresponding objects; b) that of believing that the concepts can reach a state of purity that abstracts them completely from human knowledge, which is rooted in the functioning of the body. In response, two dimensions of thought are particularly adapted: 1) *a relational dimension*: one can only compare phenomena to other phenomena (movements to other movements) and conventions are necessary. Space and time are the names of these comparisons; 2) *an embodiment dimension*: the concepts of space and time have a meaning first in the experience of the body inside the world (lived in terms of movements), before the words. The presentation of the proposal is followed by some elements of history of the concepts of space and time, a discussion on the way to express the objectivity of embodied knowledge, and some consequences that may already be foreseen, in social and human sciences, as well as in physics.

Keywords : space ; time ; movement ; embodied cognition; relational thinking; epistemology; World 3.0

1. Introduction

We will discuss here some aspects of the relations between the concepts of movement, space and time, and present our basic proposal: *movement precedes both space and time that are derived from it*^{1,2}. Although somewhat paradoxical, this way of understanding works and opens

many avenues. In some respects, some elements of the proposal are not new. But we insist that remarkable consequences appear, not only for the humanities and social sciences, but for physics itself.

In order to do justify our statement, it is necessary to go back to some kind of philosophy, and discuss the way we build our words, our concepts, our knowledge, trying to obtain some correspondence with the world. We must do with an epistemological deepening which brings to light the hidden foundations. On this level, we think it is essential to guard against two temptations: a) that of believing that reality imposes on us in a univocal way the words to describe it, each one referring to their own qualities, for themselves, of the corresponding objects; b) that of believing that the concepts can reach a state of purity that abstracts them completely from human knowledge, which is rooted in the functioning of the body.

In response to these two temptations, two dimensions of thought are particularly adapted to our study: 1) *a relational dimension*: one can only compare phenomena to other phenomena (movements to other movements) and conventions are necessary. Space and time are the names of these comparisons; 2) *an embodiment dimension*: the concepts of space and time have a meaning first in the experience of the body inside the world (lived in terms of movements), before the words. These two dimensions provide an indispensable grid of analysis, defining two axes of a plan where various mental maps can be drawn: it is in this scene that we can express our proposal and compare it to a whole series of proposals provided by the history of thought.

In the second part of the paper following the present introduction, we will explain our two-dimensional approach to discuss space-time-movement issues. In the third part, we will go into our own proposal, and provide some elements of history of the concepts of space and time, as a way to contextualize our statement. In the fourth part, we will make a stop discussing some epistemological issues referring to the status of our proposal, and present the consequences that may already be foreseen. We will end by some lines of conclusion.

2. Materials and methods: two dimensions

In figure 1, the first dimension is marked by the horizontal axis putting in scene the relational mode of rationality, fundamental for our business: we are inside the world, we can only compare the phenomena to each other, without escaping the world nor qualifying its objects in themselves in a substantial way. We will thus oppose mobility to immobility: these words have a concrete character, without prejudging the existence, or the meaning, of concepts such as time

and space. We can grasp the pair mobility / immobility from a human experience, extended in different ways by conceptual generalizations. They are qualified as relative, to underline, if need be, the comparative point of view, at a certain scale of speeds: a whole domain extends where to put the limit between the "concrete" times and spaces considered, variable according to what we are able, or want, to look at. We cannot avoid going in circles and making conventions (such as that between concrete time and space along the horizontal axis)³. Words have relative meanings to each other, depending on the context, with inevitable uncertainties and fragilities.

The second dimension, according to the vertical axis, opposes two poles, which epistemologists, psychologists, etc., have identified in our appropriation of the world ^{4 to 16}. We take this duality here for granted. It is about, on the one hand, downwards, the apprehension by the body, the gestures, the images and the imaginary, before the words; this mode includes, by extension, the experimental devices and their implementation in the measurements. And on the other, upwards, the use of words, concepts and all the discursive formalism. This dimension, contrasting images to words, is as much the one that opposes the singular to the universal, the part to the whole, the proper name to the common name, the physical to the philosophical, etc.

3. Results

We can compare two main types of evolution in the representation plane (Fig. 2).

3.1. *Our proposal*

In figure 2A we find, in the lower part, the relational source of the movements compared to each other, which leads to a first step ("stopped movements" / "continued movements"), with two concepts of concrete (experienced, measured) space and time; both are concerned by the movements where they are rooted; they are not independent.

Continuing the evolution of thought up the drawing, we arrive at the independent fictions (à la Vaihinger ¹⁷) of space and time; they get rid of the relational constraints and of the attachment to matter. It is interesting to consider each of them as an endpoint, after a whole path, rather than "*a priori* forms", or substances different by nature, pre-existing us (this avoids considering them as enigmas!).

3.2. *Other proposals in the literature. Elements of history of the concepts of space and time*

Figure 2B presents the system most often encountered in the history of science, drawn in a very caricatural way: the concepts of space and time are not proposed by paths of the previous type (anchored in the movement of the body) and their fictional character is not clearly affirmed. Their genesis is not always made explicit, it varies according to the authors (*a priori* form, property of nature given to us and over which we have no control, etc.). Links exist between the concept of time and the movements offered by the world (lower part of the diagram), but they do not appear as constitutive of the genesis of time.

Let us give very briefly further details about the way some selected authors deal with these questions.

Aristotle (4th century BC) ¹⁸. We can certainly wonder to what extent the projection of this author's system in our diagram is practicable, when for him movement has nothing relational but expresses a distinctive property of an object! In any case, what seems to us to be noteworthy is, on the one hand, the strong link between movement and time; on the other hand, as far as space is concerned, a vision very different from the one common today, opposing the imperfect sublunary world, where each body has its preferred place (where it remains motionless if it gets there), to the world of the celestial sphere whose perfect circular motion serves to measure time; this last motion is to be positioned in the upper part of the diagram. There are in Aristotle's works (the *Metaphysics*, the *Physics*) long discussions to define the division between time and movement ¹⁹. They are the premises of a true abstraction of time from movement, which will operate in Galileo ²⁰ and Newton ^{21, 22}. The fact remains that we do not have in Aristotle anything resembling the equation $\text{movement} = \text{space} / \text{time}$, i.e. a space interval travelled during a period of time.

Classical China (a few centuries before and after Jesus Christ). It has been abundantly emphasized that in classical China, that is, from the first centuries before Christ until more recent times, there was no need for the concept of time ²³. Nor is there any separate space. On the temporal side (on the side of mobility), we are faced with an assortment of seasons, epochs; these are inseparable from a set of spatial domains. There is no movement in our Western sense, but a composition of processes in endless correlation and interaction (cf. Yin and Yang). Space and time are said to be "the world as it extends" and "the world as it lasts".

Isaac Newton (1687). It is interesting to look at Newton, who clearly shows, almost in spite of himself (he wants to free himself from it), the rooting of the concepts of space and time in concrete experience (in particular human experience). According to him, we must aim at something purer, truer, which he calls *absolute time* and *absolute space*, respectively. For us, these are fictions à la *Vaihinger*¹⁷ that have shown great fruitfulness. In the spirit of the present text, we can say: the link between experience and absolute space and time is not to be unlearned, as Newton asks: it is foundational and we must go back upstream, to experience. In Newton, space and time are separated.

Immanuel Kant (1781). Kant's *a priori* forms are another way of looking at the duality that the human mind needs in order to talk about the world and that it projects onto it²⁴. To express oneself in this way (*a priori* forms) improperly gives to words an anteriority over the experience to be narrated. In Kant, space and time are always separated.

Ernst Mach (1903). This author expresses unequivocally the process of abstraction of time from the comparison of different movements, one of which will be chosen arbitrarily as a standard. The "Mechanics" should be read particularly clearly from this point of view²⁵. One can notice that, as generally, space is not discussed; does Mach think it is self-evident? The two concepts of space and time are seen in a dissociated way, despite the fact that space is present in movement. Movement has its modern meaning as the travel of a piece of space in the course of time (whose speed is the ratio between the amplitudes of space and time involved).

Albert Einstein (1905). The original point of A. Einstein is that he does not try to define at length the concepts of space and time²⁶. He takes them for granted and relies from the outset on instruments, rulers and clocks, and their implementation. The discussion of simultaneity, with a method of synchronization to test it, is also remarkable. This is already a way of linking time and space. With the two postulates, in particular the Second one, we arrive at the theory of relativity. The readings that we make on the rulers and the clocks are linked, but the corresponding concepts of space and time remain distinct. Clocks and rulers are idealized, the first are point-like, the second rigid, which is debatable. Note that, if Einstein had gone to the end of his idea, i.e. to look at how the instruments actually work, he would have opened the clocks and found that they were hiding a movement.

Henri Poincaré (1905). With Poincaré we always have two different natures for space and time, but this author (similarly to Mach) shows an interesting lucidity concerning the conventional choice of a standard (movement) phenomenon for time: it is the most convenient and not the most true²⁷. H. Poincaré also dwells on space, contrary to the authors already mentioned, and insists on the movements of our body (including those accompanied by muscular sensations) in the construction of space. This does not, however, bring time and space closer together.

Carlo Rovelli (2018). In his writings²⁸, this contemporary physicist does not dwell on the concept of space (except to proclaim its quantization, or granularity, at the microscopic level); by contrast, time is more problematic, as it is for most authors, and is the subject of long developments. If it does not exist at the fundamental level, time appears at the macroscopic level, according to a so-called "thermal" emergence²⁹; it hatches on its own, without the question of the associated space being raised, while, on the other hand, the author proclaims relativity as the obligatory passage of any physical theory, time and space forming an inseparable whole. C. Rovelli does not address the idea of a deep link between space and time, nor that of a link between space and movement. Like space, time also has the quality of granularity. It remains to be seen how this is combined with the emergence of macroscopic time. Quantization appears as an *a priori* property of matter in itself. Following our own guidelines, could quantization be rather considered as relational, as an outcome of the comparison of phenomena at different scales in a probabilistic vision?

4. Discussion

4.1. Epistemological remarks: the « World 3.0 »

If our proposal extends the history of thought and relieves certain difficulties encountered in it, it nevertheless deserves an epistemological consolidation. Does embodied knowledge lead to an objective knowledge? We need find a way to name this knowledge, independently of all the ways to support it (images, gestures, neurons, etc.). To do this, let us take inspiration from the philosopher Karl Popper^{30 to 32}. This author proposed to distinguish three "Worlds": World 1 of physico-chemical phenomena and material objects, World 2 of psychic activity and subjective experiences, and World 3 of objective knowledge (reduced mainly for this author to linguistic propositions allowing logical argumentation, demonstration, communication and debate; the

facts are reported as propositions on the same level as the other propositions). On the basis of the previous reminders, we suggest dividing the "World 3" of objective knowledge into two worlds: - "World 3.0" refers to all objective knowledge outside words; and - "World 3.1." corresponds to Popper's "World 3" (Fig. 3). World 2 has overlapping domains with World 3, but it has its own parts that escape objectivity.

Worlds 3.0 and 3.1 constitute two non-watertight poles, between which specialists (semioticians, psychologists, neurophysiologists, anthropologists, etc.) will find intermediaries (see, for example the epistemology of sign language). The whole question of the passage from gesture to words arises here³³, and would deserve a complementary discussion: it is at the basis of the reflections of the present text.

There is a certain porosity between World 1 and World 3.0: but the latter is more than a "raw" sum of phenomena, more than an unconscious passive incarnation. If we speak about knowledge, it is because the phenomena appear there as put to the test, tried, experienced, repeated. There is an appeal to this substratum in a conscious, organized way, with a certain validation by the results (cf. the football player who goes to recover the ball at the very place where it is necessary, without writing mechanical equations; but who can also miss his shot!). This knowledge is "structured", as a form of intuition, or internal adhesion, guarantees it.

4.2. Shifts in meaning and misunderstandings

The meanings of the words time, space and movement, shift depending on where they are pronounced in our diagram. The horizontal shift corresponds to the concrete time-space transition according to the choice of a {spatial frame / standard mobile} pair. Vertically, we distinguish, on the one hand, concrete space and time (stopped movements / continued movements), chosen via a convention of stopping by a given community in a relational process, which is the only one practically possible; and, on the other hand, the fictions of space and time that allow us to think and say; the first behave like proper nouns, the second like common nouns. There are possible intermediaries between the one and the other, varying according to the context, and they cannot be separated once and for all; hence the possible misunderstandings. But we commonly use the same vocabulary, it is the most convenient, it would not be practical to operate otherwise. The shift in meaning is difficult to avoid. We must have a tool with a certain generality (it gathers by abstraction all the singular objects inspected), and at the same time be able to speak of such and such a particular object, with the same word. Or again, to say

a concrete relation between A and B, we need the fiction of separate A and B; but we still speak of A and B.

We can compare these language processes to what Vaihinger says about fiction, using the example of the word "tree". A "tree in general" (a common noun) is a fiction, and as such not free of contradictions: it is both green and not green (red or orange in autumn); it has both leaves and no leaves (thorns), branches or not, fruits or not, etc. But we arrived at this tool of thought after having seen and compared multiple plant objects. The tree in general does not exist: no scientific study can be made of it, no analysis. On the other hand, when we are faced with a particular object, the association of the word tree and the designation ("look at this tree") almost transforms the word into a proper name, on which we can effectively make an analysis. It is more convenient to speak of a tree, located at such and such a place (we also detach the tree from space and time) rather than finding a proper name for each tree.

In order to avoid misunderstandings caused by meaning shifts, we can propose to change the words used, at least momentarily, in order to make the status of our proposal clearer. Figure 4 replaces figure 2 by using new words. We can thus replace the proposition "movement precedes space and time" by: "pre-concept of movement (situated in World 3.0) precedes the pure concepts of space and time (situated in World 3.1)". This formulation is a shortcut that hides several steps detailed in the figure.

4.3. Consequences foreseen in humanities and physics

If we believe there is some "efficiency" to the two dimensions of thought presented, it seems important to outline their numerous consequences, as an encouragement to their appropriation (remember Bergson: "an idea is enlightened by what it enlightens"). Let us say a few words about them on a prospective basis. In all fields of thought, when it comes to deepening this or that situation, we consider that there are serious drawbacks to separating concrete space and time. Physicists have every interest in not letting themselves be intimidated by the mystery of fictional time, making the mistake of taking it for a reality. We must try as much as possible to go back to the source: spatial amplitude and temporal process are the two faces of the relation between movements ². It is fruitful to consider a lapse of time as a piece of movement: it provides, for example, a key to discuss the twins paradox, to alleviate the problems of Wigner-Thomas rotations in the composition of non-collinear Lorentz transformations (time has a direction that projects itself like the other spatial directions), or to take up the expression of the

gamma factor of the Lorentz transformation (after opening the clocks and taking into account the movements that are hidden there³⁵). It is fruitful to consider an amplitude of space as a piece of movement, it allows in particular to understand the definition of the meter (1983). It is fertile to put time and space on the same level, and on the same level as the different pairs of quantities of physics; this allows, among other things, a new look at the relations between quantum mechanics and general relativity³⁶, at the second law of thermodynamics³⁷, its spatial and temporal gradients or at the unexpected familiarity between the second law and the second postulate (relativity)³⁸. It is profitable to strongly match time, space and movement in the human and social sciences³⁹: it brings new insights on the aporias of time, on the relations between history and geography, on the role of space on the identity of migrant peoples, on the convergence of the words of time and space in linguistics, on the understanding of rhythms⁴⁰, on the genesis of spatio-temporal notions in anthropology⁴¹, psychology and neuroscience. And so on. We would find it difficult to concede that all the elements of this ensemble, which only asks to grow (and despite its provisional character at the moment), are only a product of the Coué method?

5. Conclusion

In conclusion, we promote a strong distinction between, - on the one hand, space and time as separate fictional objects (seen according to a philosophical viewpoint) indispensable for thinking and saying, the endpoint of a whole path, and not as founding principles; and - on the other hand, space and time that count (real, actual, singular, lived, experienced, measured, ...), linked like two sides of the same coin (the comparison of movements : stopped movements / continued movements); it is them that physics studies, upstream of the fictions they will generate. Between the two extremes, there is a shift of meaning or polysemy, and, much more, a change of status of words. The return to concrete space and time, linked in movement, opens up a great many avenues, both in the human and social sciences and in the "hard" sciences (even in the way equations are played and calculations are made): it is very fruitful to put movement upstream of space and time: these may thus be compared and considered together in the same thought experiments.

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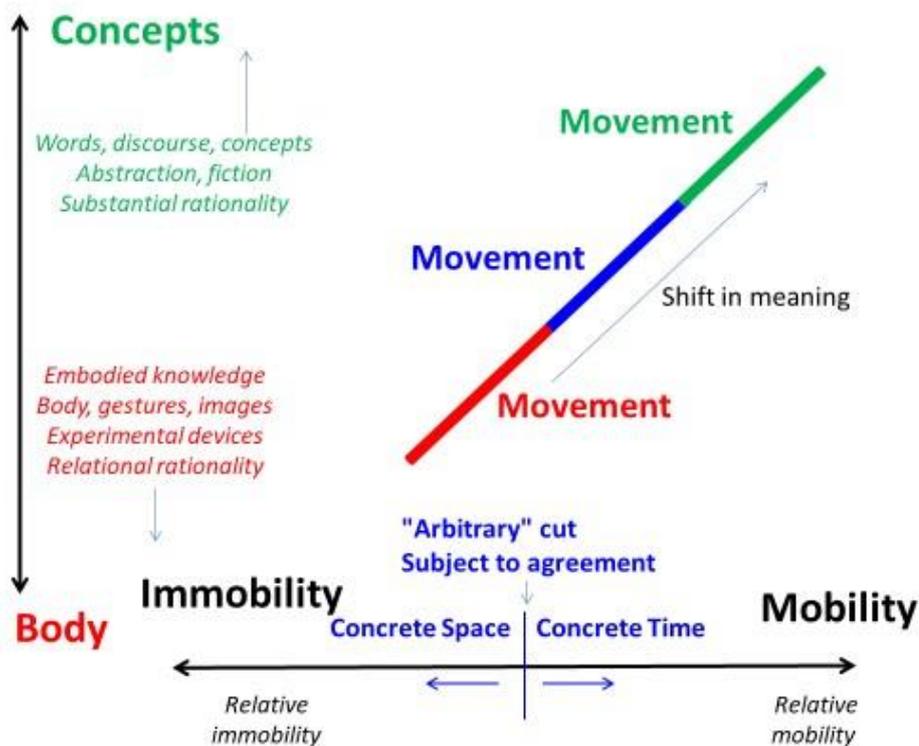


Figure 1: Two dimensions useful for our discussion

Two dimensions: {concepts / body} along the vertical axis, {mobility / immobility} along the horizontal axis.

Horizontal axis: relational dimension, opposing mobility to immobility; or better, what goes slower to what goes faster (cf. the qualifier of relative); these are germs of space and time, qualified as concrete or physical; after a separation to a place subject to convention.

Vertical axis: dimension of incarnation, seeing a continuum between knowledge in the body (downwards) and more abstract concepts (upwards).

Shifts in meaning and color codes: depending on the position in the plane, the same words may have different meanings. We put dissimilar colors to the words according to the levels of altitude where they are located: in red, downwards, for the incarnation in the body; in blue after first comparisons and conventions, in a median position; in green upwards, concepts which tend to separate from their material sources, up to fictions. Thus the word "movement" will have different meanings in the figures according to its altitude.

In the text, we insist on the "ascent" of meaning from the knowledge of the body to the concepts used by the mind; but there is another movement, a descending one, which allows us to *attach a word* to what is played out at the bottom thanks to the linguistic tools created at the top. This descending line completes the complex circularity (à la Morin) between the different levels. Both lines are inseparable.

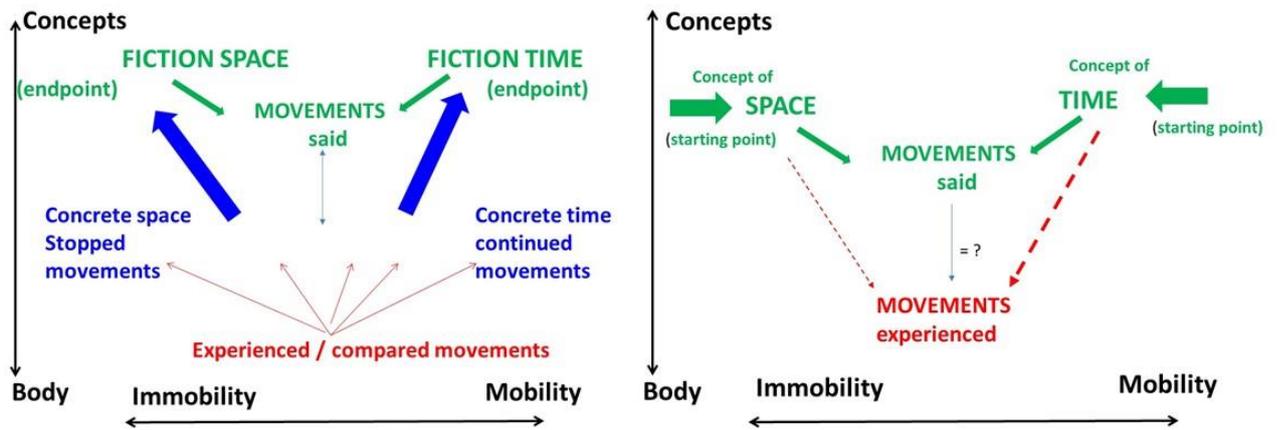


Figure 2. Elements of synthesis

Figure 2A on the left summarizes our proposal, figure 2B on the right is a kind of summary of the current standard understanding. In A space and time are first understood in a concrete way as comparisons of movements (this is the source, red and blue) before "becoming", as the result of a thought process, pure fictions in the sense of Vaihinger.

In contrast, in B, time and space appear rather as starting points, whether or not they present a relationship, to be specified, with movements. The stage of extraction, choice and convention from the movements is absent, the said and experienced movements not being seen as different from each other. The absence of the blue stage in 2B especially manifests the absence of the use of relational rationality.

The paths in A are presented ascending; the descending paths are implicit: they are the ones that allow us to draw the blue and red words with the green vocabulary (which is itself the top of the ascending paths).

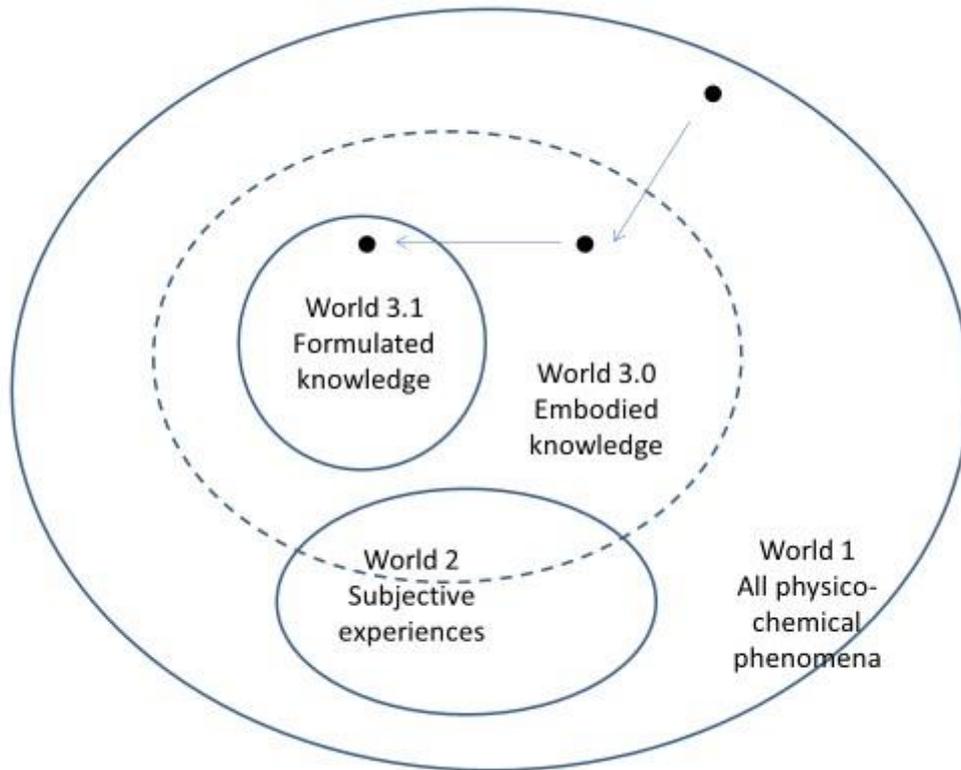


Figure 3. The three “Worlds” of Karl Popper.

Proposal for the development of World 3 (objective knowledge) into two Worlds 3.0 and 3.1. One does not go directly from World 1 to a formulation in World 3.1 (formulated knowledge), a "step" is necessary in World 3.0 (embodied knowledge). This is the name of the path marked here by the two arrows connecting the three points of the drawing. The limits of such a representation lie in the difficulty of isolating pieces of the world from each other and representing them by the patatoids of set theory and in the porosity between the different "Worlds".

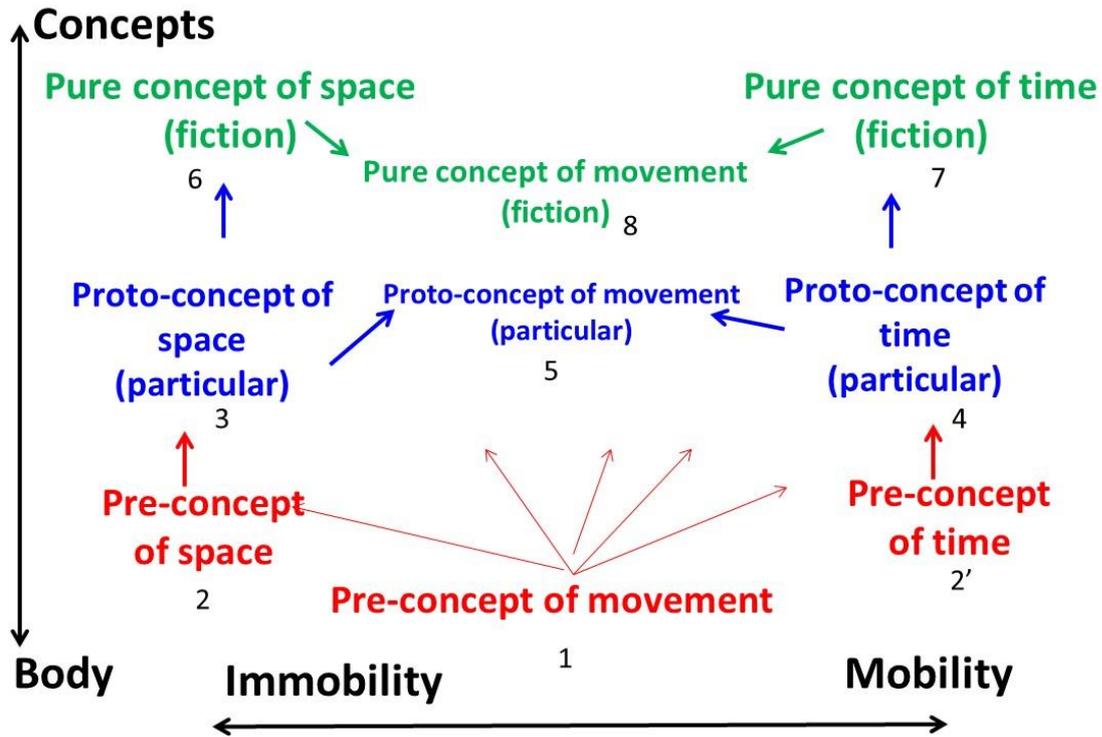


Figure 4 Movement, space, time: from pre-concepts to pure concepts

Association of different expressions to the words time, space and movement, in order to make understand the shifts of meanings and of epistemological status. The numbers follow the progression of thought. We will thus speak at the beginning (step 1) of the *pre-concept* of movement, to designate the sensory experience (vision, proprioception, ...) of movement, before the words. The sensory experience of space (one bumps into something, one cannot continue the movement) and of time (something can continue elsewhere) follow together (this is why they are assigned the same step 2 / 2'). One can then name and formulate, respectively for space and for time, and independently now of each other, true discursive concepts in relation to what one will have shown (steps 3, 4); one speaks about *proto-concepts* because it is still associated with a particular world; one can deduce from them a proto-concept of movement (5). In a final step, through a process of inductive generalization, space and time are completely freed from their relational aspect and from their material support and we build concepts qualified as "pure" for space (6), time (7), from which we derive a concept of pure movement (8). The steps 1, 2 and 2' situate us in the world 3.0; the steps 3, 4, 5 are situated in the world 3.1 but at the border with the world 3.0. Steps 6, 7, 8 are clearly in world 3.1.