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RESEARCH ARTICLE



'Bringing time back in'. Towards a socio-ecological stratification of time

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ABSTRACT

This article aims to contribute to 'bringing time back in' environmental sociology. Drawing on the work of Michael Carolan and Henri Lefebvre, a new analytical framework is set forth. It connects an ontological social-biophysical stratification of time (*what is time?*) and a time epistemological quartet (*how do we develop knowledge claims about time?*). These analytical inputs open up new research avenues to overcome the epistemic barriers related to temporality as well as new insight on how to cross the great divide between 'natural time' and 'social time'.

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Introduction

Time inconsistencies is probably one of the greatest challenge in the Anthropocene. The mismatch and the interlinkage between the multiple and complex temporalities in the biophysical and sociocultural realms act as drivers of catastrophic environmental changes. 'Natural time' was long considered as homogeneous and 'largely immutable' (e.g. Elias 1992; Murphy 2001; Bansal and Knox-Hayes 2013) in comparison with the perceived time-space compression of social life (e.g. Giddens 1990; Rosa 2015). Most of the work in sociology of time focused on the sociocultural realm. The development of new devices and techniques helped us to better understand and visualize the multiple and unique temporalities of ecosystems and Earth-system processes. Acceleration, temporal extension, uncertainty, irreversibility, tipping-points are increasing being recognized as key temporal features of these geobiophysical processes considered as planetary boundaries. However, the epistemic barriers (Carolan 2006) are numerous when it comes to fully grasp the temporalities of those threats as well as the complex interactions with the temporalities of socio-political conventions. Striking illustration, the COVID-19 pandemic, has led us to concretely experiment with some of these attributes, notably the exponentiality and radical uncertainty (Ruwet, 2021).

Yet the entanglement of temporalities between and within the biophysical and the sociocultural realms is seldom the focus of research. This paper therefore raises the following question: In an interdisciplinary perspective, how can we develop an analytical framework enabling us to work across 'natural' and 'social time' thereby critically investigating their interlinkages?

To answer this question, I will build on the work of scholars who developed a socio-ecological theorization of time (Elias 1992; Adam 1998; Urry 2000; Murphy 2001; Newton 2003; Bansal and Knox-Hayes 2013; Lockie 2014; Lockie and Wong 2018). They highlight the need to reconsider the dualistic distinction between 'social' and 'natural' time. Yet crossing the great divide is not an easy task. If they are mutually constitutive, they are also relatively autonomous. The main assumption in this paper is the following: The ontological understanding of time is closely related to our ontological understanding of nature. Introducing time 'back into nature' with an ontological depth is deemed important because 'it was precisely by assuming nature as *constant* that sociocultural reductionists justified neglecting and bracketing nature in the first place' (Carolan 2005, 400). The first step, therefore, involves reconsidering the very ontology and epistemology of time and bringing it back into 'nature'.

To do so, we must make a distinction between two dimensions of time that are often conflated in the literature: the ontological dimension (*what is time?*) and the epistemological dimension (*how do we develop knowledge claims about time?*). It is also important to differentiate time from temporality. In this paper, temporality will be defined as the multiple temporal features associated with 'natural' and 'social' processes and their interlinkage such pace, rhythmicity, duration, speed, intensity, synchronicity, timing ... Depending on the epistemological standpoint, these multiple and complex temporalities can be perceived and experienced by individuals, socially organized (within and across in culture, organizations), analyzed and control through devices, technologies ...

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The paper is divided into three sections. In the first section, highlighting the similarities of the longstanding debates between the realist and constructivist approaches around the definitions of nature and time, I will suggest connecting these two research topics. Drawing on relational realism, I will suggest bringing time back into nature and clarify the confusion between the ontology and epistemology of time. The second section theorizes an ontological social-biophysical stratification of time inspired by the social-biophysical stratification framework (Carolan 2005; Stuart & Carolan, 2016). I will argue for the need to deepen this analytical framework to critically investigate the various practices involved in the social production and reception of knowledge about time. Pursuing this endeavor, the third section discusses Henri Lefebvre's spatial triad, which is very useful when reflecting on the various epistemologies of time. A critical analysis of his work will help me set forth an epistemological quartet to analyze the mechanisms of social production and reception of knowledge about time. The final section discusses the potential implications of the analytical framework to overcome epistemic barriers related to the temporalities of biophysical and sociocultural processes as well as their interlinkages thereby opening new avenues for research and environmental governance.

Crossing the great divide: socio-ecological theorizations of time

Just like 'time', 'nature' is a concept that is very difficult to grasp due to its imprecision and multidimensionality. Indeed, both concepts exist as social constructions as well as physical realities. The sociology of the environment and the sociology of time emerged during the same period.¹ In the 1970s, both disciplines started to challenge the prevailing tendency to consider the biophysical environment and time, respectively, as unquestioned background conditions.

Broadly speaking, as far as the relationships between nature/time and society are concerned, a similar, longstanding debate exists between a realist and a constructivist approach in each of these two fields. Discussions over the nature-society divide have shaken up the environmental sociology discipline for more than three decades (Catton et al., 1978; Freudenburg, Frickel, and Gramling 1995; Murphy 2002). The same realist-constructivist divide holds for the theoretical approaches around time in social sciences. In a realist perspective, time in its biophysical dimension is considered a given and should be left as an object of inquiry for physicists (Elchardus 1988). Research in social sciences focuses mainly on the variety of time's perceptions. At the other end of the spectrum, in a constructivist perspective the very definition of time is considered to be a social

phenomenon that should be investigated and not taken for granted. The way time is conceived is a social construction, it is historically contingent, and influences social order and social change. In a sociohistorical perspective, many scholars have studied the progressive abstraction, standardization, universalization and commodification of time associated with phenomena such as modernity, industrialization, the rise of capitalism and globalization (e.g. Zerubavel 1982; Bourdieu 1990; Giddens 1990; Rosa 2015). Time-space compression (Giddens 1990) and the acceleration of the pace of life (Rosa 2015) lead to the progressive disconnection from local contexts and natural rhythms (Zerubavel 1982; Adam 1998) and blind us to environmental degradation and social injustices occurring around us.

Since the beginning of the 2000s, and concomitantly in both fields, some attempts have been made to bridge the two perspectives, which once seemed irreconcilable – from realist constructivism (Murphy 2002) to relational realism (Carolan 2005; Carolan and Stuart 2016). The main idea behind these new approaches is that the social construction and the biophysical dimensions of these concepts are entwined and should be a full-fledged field of social science analysis. Analytically, two major aspects behind this debate are often confused with one another: the *ontological* and the *epistemological*. In other words, on the one hand, we have the study of the reality of existence and becoming (ontology) and, on the other hand, questions over the diverse forms of knowledge of this reality (epistemology). Strong realism typically argue that nature/time have a biophysical reality outside of human interpretation *and* that one type of knowledge (the natural sciences, in particular) enables us to understand the true and universal nature of this reality. In stark contrast, strong constructivists assume that nature/time do not have any reality as such. This ontological approach can lead to complete cultural relativism in terms of epistemology. I will argue that drawing a clear distinction between these two questions is essential.

Among the dearth of research which developed a socio-ecological theorization of time (Braudel 1972; Elias 1992; Adam 1998; Urry 2000; Murphy 2001; Newton 2003; Bansal and Knox-Hayes 2013; Lockie 2014; Lockie and Wong 2018), one of the key issues is to reconsider the classical dichotomy between 'natural time' and 'social time'. Yet the anti-dualism standpoint leaves the question of *equivalence* open. Leading scholars in the field such as Adam and Urry claim that 'habits of the mind' and notably the Newtonian vision of abstract, absolute, and linear time had a considerable influence on the modern social construction of time leading to phenomena such as the disconnection with biophysical processes or the commodification of time. In the quest for more appropriate bases of understanding

and environmental actions, they argue that the conception of time in post-Newtonian science (especially that associated with quantum mechanics, the second law of thermodynamics, and chaos and complexity theory) can be applied both to the biophysical and the social realms. Newton (2003) suggested that the risk of this type of theorization is to bypass the ontological and epistemological differences between the natural and the social temporalities. Ultimately, the risk is to 'fail to account for the ontological asymmetry that exists between the two realms – namely, that although the biophysical can exist without the social, the converse is categorically impossible' (Carolan 2005, 394). In this perspective, 'social' and 'natural' time are not equivalent as earth-system processes are characterized by specific and autonomous temporal features such as their plasticity and their pace of change – the latter showing remarkable variations both phenomenal speed and extreme slowness.

The challenge is thus to incorporate the multi-directional interactions between temporalities in the biophysical and the socio-cultural realms in a single theoretical framework. Fernand Braudel (1972) is probably the most well-known scholar who has introduced the idea that historical time has different layers, each with its own temporal duration and rhythm (i.e. the slowly changing *longue durée* of geographical time, the medium-term conjunctures of structural history, and the rapidly changing history of events). If this approach acknowledges that society and ecology are actively shaping each other's (Moore 2003), the autonomy, multiplicity, and complexity of the temporality of 'natural' processes are downplayed. In other words, the division in three scales on a continuum is above all methodological rather than ontological. Braudel's emphasis on human agency conflates the epistemology and the ontology of time. It thereby disregards the fundamental difference of the processes occurring within the three layers and, most notably, the invisibility of some phenomena as well as our incomplete knowledge or misunderstanding of many

geobiophysical processes. I will argue that critical realism and, especially the relational realist approach developed by Carolan, is a fruitful avenue to comprehend the complex ontology of 'time' in its relationships with 'nature'.

Time ontology: what is time?

Drawing on Bhaskarian critical realism (Bhaskar 1978) and the two categories of nature depicted by Soper (1995), Carolan (2005) developed a social-biophysical stratification framework based on three fluid and interpenetrating strata: Nature, nature, and 'nature'. These three categories encompass different types of bounded hybridity between the biophysical and the sociocultural realms, ranging from physical phenomena to discursive practices. More recently, a revised version of the framework (Carolan and Stuart 2016) overlaid more explicitly the Bhaskar's three levels of reality (the real/the actual/the empirical) with Carolan's three nature's framework thereby including the influence of 'real' social forces such as the treadmill of production or neoliberal ideologies in the shaping of social-biophysical relationships.

To my knowledge, time has not been explicitly incorporated into Carolan social-biophysical stratification analytical framework.² Yet this framework is extremely useful when it comes to understanding the specificities of time's ontology. Indeed, each of the three strata defining nature (that is Nature, nature, and 'nature' presented in ascending order of ontological depth) can be associated with its corresponding time stratum (see Figure 1).

The ontological stratification of nature and time

The first and deepest stratum (Nature) corresponds to phenomena of physicality and causality, such as gravity or the laws of thermodynamics. Our knowledge of this reality is incomplete and socially mediated. The

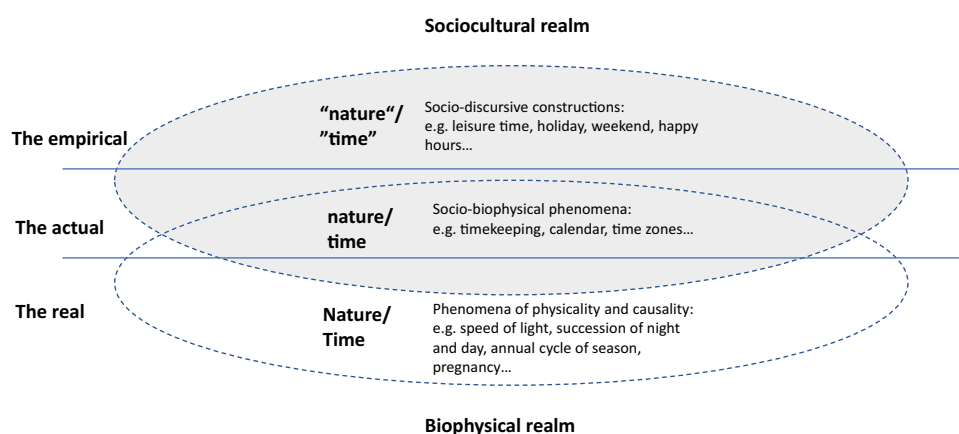


Figure 1. The interpenetrating sociocultural and biophysical realms that constitute time ontology. Adapted from (Carolan 2005) and (Carolan and Stuart 2016).

development of the natural sciences and their related devices has helped us better understand 'Nature phenomena' but the result is inevitably partial, i.e., highlighting some aspects of reality while excluding others. At this level, time is the pace of the ecosystem, such as the speed of light, the annual cycle of seasons, or the perpetual succession of night and day. As biological bodies, human beings' life cycles are embedded in this Time of Nature. For example, pregnancy duration is universally around nine months and the development of the fetus undergoes the same natural stages.

The second category (nature) refers to the observable sociomaterial nature, both shaped by, and shaping human activities, such as fields, forests, the ozone layer, or diseases. Here, there is an obvious overlap between sociocultural and biophysical realities. Correspondingly, in our everyday-life definition of time, these two realities are entwined. Timekeeping is intrinsically linked to the length of the Earth's orbit around the sun but has also become socially constructed. In fact, the division of the day into twenty-four identical periods of sixty minutes comprising sixty seconds each is relatively new in human history and was only made possible by the development of specific devices, such as the mechanical clock. Standard Time (time zones defined on the basis of territorial boundaries) was not formally globally established until the late 1920s. These historical changes have deeply altered our sense of time and place. Yet this standardization of time is not completely removed from physical realities.

The third layer ('nature') designates socio-discursive constructions regarding the naturalness of specific practices within a society. Accounting for the perpetuation of power relationships in the name of 'nature' has been a recurrent strategy throughout history – from slavery to gender discrimination. Similarly, 'time' can be purely a socio-discursive construction. Zerubavel (1987) examined this 'language of time', that is the manipulation of time 'as a virtual code through which they convey important social messages without having to articulate them verbally' (Zerubavel 1987, 344). Throughout history, society – and especially religions – has played a crucial role in assigning different symbolic qualities to time (Elias 1992). The introduction of temporal contrast, with the sanctification of 'holy days', was used to substantiate the elusive conceptual contrast between abstract cognitive categories, such as the sacred and the profane, or the extraordinary and the ordinary (Zerubavel 1987).

The strong articulation between time and nature in the three strata (Nature-Time, nature-time and 'nature-time') seems obvious. This representation of reality is nevertheless an approximation. Carolan insists that 'critical realism does not assume a one-to-one correlation between knowledge claims and reality; one must be careful not to conflate critical realism with mere

empiricism. Critical realism acknowledges that there is a distinction between the way things are and our knowledge claims about those objects of knowledge' (Carolan 2005, 396).

Our representations and relationships to nature and time are mediated by knowledge. However, the status of epistemology varies in the three strata. Whereas the real (Nature/Time) exists independently of human knowing, the empirical ('time') is wholly dependent on shared epistemologies. Carolan's conceptual framework does not go as far as providing analytical tools to understand the various practices involved in the social production and reception of knowledge about nature in the three levels of reality. Research that has applied the social-biophysical stratification framework to concrete cases (Houser, Carolan and Stuart 2016; Besek 2019) tends to associate some of the strata with specific epistemology: the empirical is linked with beliefs whereas the actual is studied through perceptions. Yet developing a critical stance on the temporality embodied in knowledge practices (Lockie 2014) is essential if we are to understand possible pathways to overcome epistemic barriers to sustainable practices. The risk is to overlook some dimensions such as the power associated with knowledge production, the domination of certain type of epistemologies and the potential benefits of diversifying the epistemologies to foster social change.

Time epistemologies: how do we develop knowledge claims about time?

Explaining the ontology of time is not enough to capture the different patterns of its social production and reception. In order to grasp the roots and the specificities of the mounting environmental degradations and threats, as well as potential pathways to tackle them, we also need to develop an epistemological perspective. In other words, if our current understanding of time is misleading and detrimental, we must explore the ways in which we currently develop knowledge claims about time and search for alternatives. 'We have to turn the reflective attitude on our own knowledge bases and begin to question the "natural" place of these presuppositions in our ways of knowing' (Adam 1998, 43).

Following a classical assumption in human geography (e.g. Harvey 1990), I will argue that the mechanisms of social production and reception are similar for time and space. Henri Lefebvre (Lefebvre 1992; [1974]), now recognized as one of the key contributors to environmental sociology (Foster et al. 2020), is often credited with introducing the idea that space is socially produced. In his work, space and time are considered 'the indispensable coordinate of everyday life, and therefore a rethinking of them is essential to that overall project' (Elden 2004, 170). He paid specific attention

to the analysis of historical variations in the shaping of space, showing how it served as a tool for thinking and action, but also as a means of control and domination. 'Lefebvre argues that space is the ultimate locus and medium of struggle and is therefore a crucial political issue' (Elden 2004, 183). He offered a useful conceptual triad when it comes to explaining the multiplicity of space epistemologies. Although this typology has not systematically been applied to time, I will argue that it offers interesting analytical insights.

Lefebvre's spatial triad

For the analytical purpose of this article, and since our aim is not to discuss Lefebvre's work at length,³ we will build on a somewhat simplified version of his typology. In a nutshell, space can be *conceived* (when abstracted as signs and codes by scientists, engineers, geographers, etc.), *lived* (beliefs, symbols associated with certain spaces shaped by cultures, ideologies or the imaginary) or *perceived* (i.e., experienced through the senses).⁴

Lefebvre (Lefebvre 1992; [1974]) used the metaphor of the body to explain the differences between these three dimensions: the *conception* of the body is derived from accumulated scientific knowledge (such as anatomy or physiology), bodily *lived* experience is influenced by our beliefs (such as the Judeo-Christian tradition, for instance), whereas the use of the limbs and sensory organs drives our *perceptions*. 'The "heart" as lived is strangely different from the heart as thought and perceived' (Lefebvre 1992; [1974], 40).

Yet Lefebvre insisted on the possible interconnection between these three dimensions: the abstract conceptualization of space may influence our beliefs or our perceptions, for instance. However, they do not necessarily constitute a coherent whole. 'A park is *conceived*, designed and produced through labor, technology and institutions, but the meaning of the space, and the space itself, is adapted and transformed as it is *perceived* and *lived* by social actors and groups' (Elden 2004, 191). A common language, a consensus, and a code need to be established. These allow the individual members of a given social group to move from one understanding of space to another without any confusion.

Drawing on Lefebvre's spatial triad to build a new analytical framework

Broadly speaking, if the distinction between 'conceived space' and 'perceived space' offers some interesting insights, the concept of 'lived space' is more ambiguous. Tracing back the history of Lefebvre conceptualization, Elden (2004, 186–188) asserts that the notions of 'conceived space' and 'perceived space' originated in Descartes distinction between *res cogitans* (reduction of geometric space to thoughts or pure idealism)

and *res extenso* (realization of space outside all thoughts, physical or pure materialism). Using a dialectic method, the concept of 'lived space' was formulated as a bridging concept in an attempt to resolving the conflicts between the two without being reducible to either. This third term 'sees space as produced and modified over time and through its use, spaces invested with symbolism and meaning, the space of *connaissance* (less formal or more local forms of knowledge), space as *real-and-imagine*' (Elden 2004, 190). An analytical comparison between these concepts highlights two major dimensions: (1) institutional-subjective and (2) contextualized-decontextualized (see Table 1).

First, there is a distinction between the *institutional* and the *subjective* aspects of knowledge production around space. In other words, accepted common rules and procedures associated with cognitive frameworks internalized as collective constraints by individuals that shape knowledge production and reception (institutions), on the one hand, and, on the other hand, the ability to produce singular meanings through the individuals' cognitive *and* affective systems, the materiality of the body and intersubjective relations (subjectivities). Whereas conception is an institutional activity based on collective rules of production – such as peer reviews or internal validity – perception is subjective because it derives from each person's sensory organs and may therefore vary with time, depending on internal and external factors (state of health, age, time of the day, weather conditions). In between these two poles, there is the *lived* space, which embodies the subjective experience of human sense-making based on representations of space acquired through the filter of cultural background, immanent experiences and relations.

Second, perception entails a specific *context* and can be considered as a local, colloquial form of knowledge whereas conception is abstract, decorporalized and *decontextualized*. In between these two poles, the lived space encompasses both contextualized and decontextualized elements. In that respect, from an activity point of view, 'context' can be defined as all the qualities that surround and influence a specific experience. These qualities can either be perceived through bodily sensations or linked with meanings (beliefs, symbols ...) associated with a specific location or activity.

Broadly speaking, a parallelism can also be drawn with the classical distinction between space (as an abstract physical location based on formal knowledge)

Table 1. Lefebvre's spatial triad classified in two dimensions.

	Decontextualized	Contextualized
Subjectivity	<i>'Lived'</i>	<i>Perceived</i>
Institutions	<i>Conceived</i>	<i>'Lived'</i>

and place (an area that is given a specific meaning through human experiences and relations, either directly through the senses or indirectly through symbols and ideologies). Indeed, the same location may be viewed either in terms of space or place. 'Place implies space, and each home is a place in space. Space is a property of the natural world, but it can be experienced. From the perspective of experience, place differs from space in terms of familiarity and time. A place requires human agency, is something that may take time to know, and a home especially so. As we move along the earth, we pass from one place to another. But if we move quickly the places blur; we lose track of their qualities, and they may coalesce into the sense that we are moving through space' (Sack 1997,16 in Agnew, 2011). Although Lefebvre never explicitly referred to the term 'place', 'space' may be considered the realm of the conceived, whereas 'place' is the realm of the perceived and the lived (Agnew, 2011).

Toward a temporal quartet

Lefebvre's spatial triad is a useful tool for reflecting on the various epistemologies of time but, somehow, it is incomplete and misleading. The concept of 'lived space' encompasses several elements that would be worth specifying. In this section, drawing from my analysis above of the two dimensions structuring knowledge production around space (i.e., institutional-subjective and contextualized-decontextualized), I will suggest an analytical framework to study the mechanisms of social production and reception of time – time

is not only *conceived* and *perceived* but also *imagined* and *planned* (see Table 2).

Imagination, conception, perception, and planning are cognitive functions embodied in a cultural context. In contemporary sociology, time is mostly studied by scholars active at the junction of cognitive and cultural subfields (e.g., Zerubavel 1987; Snyder 2019). The epistemologies of time are not fixed once and for all. The content of these different dimensions and their relationships are dynamic and influenced by historical processes, such as industrialization or globalization. Cartesian views of space and time have long dominated our world view and our relationship to nature (Lefebvre 1992; [1974]; Adam 1998; Macnaghten and Urry 1998). Conversely, the future evolution of these epistemologies is uncertain and will be influenced by human agency.

My aim here is not to adopt a sociohistorical perspective. Therefore, I will not explain in detail how time epistemologies have been constituted, or what their consequences are but, rather, illustrate each of the categories in its relationships with the literature.

I argue that in contemporary western societies *time conceived* and *time perceived* are mostly used to apprehend the biophysical realm, whereas *time imagined* and *time planned* shed light on the sociocultural realm (see Figure 2). 'As Lefebvre suggests, with modernity lived time experienced in and through nature gradually disappears.' (Macnaghten and Urry 1998, 141). In other words, in search for universal and formal truths *time conceived* is usually considered to be more attuned to the understanding of the geobiophysical realm.

Table 2. Temporal epistemological quartet.

	Decontextualized	Contextualized
Subjectivity	<i>Imagined</i>	<i>Perceived</i>
Institutions	<i>Conceived</i>	<i>Planned</i>

Time conceived

Time as a biophysical reality has been analyzed and abstracted mainly by scientists. At the heart of modern science lies an ideal of timeless formalism. In that

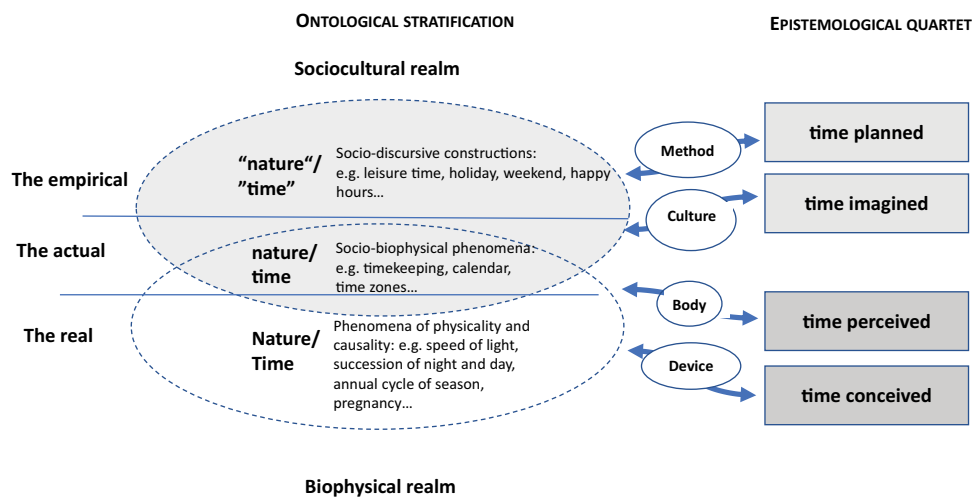


Figure 2. Dominant relationships between time ontology and epistemology in contemporary western societies.

perspective, conceiving time and, more broadly the temporality of social-biophysical processes, is first and foremost a highly rational activity occupied by concepts, logics, and measurements – reducing reality to mere thinking. Time is analyzed as an external phenomenon, be it physical (Time) or social-biophysical (time).

For instance, the idea that light has a specific speed that can be measured was conceived by Galileo. Over the centuries, many scientists have worked on this phenomenon, trying to invent new methods and devices for measuring the speed of light. For scientific devices and objects play a mediating role in accessing what is invisible (Birth 2012). Developments in disciplines such as physics and mathematics in the past decades have helped us improve our understanding of the complexity of Time. Indeed, our modern conception of Time is at odds with the intuitive definitions by Galileo and Newton, who conceived time as linear and absolute. Einstein showed that rates of time run differently depending on relative motion. This reality is difficult to apprehend for most people because it contravenes our general perceptions. Scientists thus help us visualize and conceive what is invisible.

But the deepest layer of Time is not the only one that is conceived, time has also been studied and shaped. 'As early as 1939, Lefebvre had described geometric space as abstractive and likened it to clock time in its abstraction of the concrete' (Elden, 2, 187). Clock time is not the only option available for time reckoning. As explained before, the dominance of the clock is the result of a process of standardization and formalization (Zerubavel 1982; Giddens 1990): 'time' was conceived this way. 'The merger of different modes of time reckoning and the dominance of the measure of duration have become hidden assumptions (...). The devices themselves have come to shape our thinking about time' (Birth 2012, 43).

Time perceived

The production and reception of knowledge regarding time is influenced by our *perceptions* of its different forms. In other words, we experience temporality through our senses. Vision is often considered to be time-specific enabling a sense of movement over and through time, but the other senses have also temporal features. For instance, smell, sounds or taste are particularly relevant to our memories (Macnaghten and Urry 1998). With its subjective and context-based features, time perceived is more attuned to the empirical. It can be associated with the classical category of 'event time'. In other words, perception requires being bodily immersed in time. 'This sense of event time is what we talk about when we say that time *feels like* it is flowing fast or slow, staccato or legato, is full and intense or empty and unstimulating' (Snyder 2019, 647).

Broadly speaking, two main factors influence our perception of time: our age and our general state, be it mental, emotional and/or physical. Aging, as a reminder of our biological selves, may be viewed as a dimension of Time. Human beings experience Time (in its deepest stratum) in very different ways during their life cycle. Behavioral and neuroscience research have underlined a strong connection between Time awareness and the development of the brain. 'Developmental psychologists have shown that young children initially cognize time in terms of their engagement with context-specific events' (Snyder 2019, 648). Very young infants are immersed in Time and are not able to make any explicit time judgment, namely estimate the duration of an event or project themselves in the future. In other words, 'they cannot engage in "temporal decentering" – the ability to "adopt a temporal perspective on an event from a point in time that may not coincide with the time of the event itself or with the present time"' (McCormack and Hoerl 2008, 91 cited by Snyder 2019). Time awareness develops during childhood in part in connection with the maturation of the brain.

The perception of time (for instance, the division of the day or the year into time units) also varies depending on our emotional and physical states. Psychologists have shown that fear alters our sense of time: When confronted with life-threatening events, time appears to slow down. Similarly, mindfulness influences duration perception.

Time imagined

One of the oldest ways to develop knowledge claims about time is through our imagination, namely our creative mental ability to form images and ideas without any necessary *immediate* contextual inputs. These ideas and symbols are derived from culture (i.e., the values and beliefs transmitted by ethnic, religious or social groups) and influence them, but the process of imagining is first and foremost a subjective one (i.e. it requires the involvement of individuals' cognitive *and* affective systems and the ability to produce singular meaning in relation with one's own trajectory).

The understanding of time is associated with specific meanings and symbols. Castoriadis has emphasized this 'imaginary' dimension of time epistemology: It is in imaginary terms that ideas such as 'boundary', 'periods', and 'quality of time' are posited (Castoriadis 1997). First, the notions that time has a beginning and an end, or that there is a date, or a moment when the world was created, or repetitive cycles, are linked not only with religious and cultural meanings, but also with images and storytelling. Second, imagination is intimately associated with meanings given to the periodization of time, acting as a reference point in individual trajectory. A calendar is not just a simple succession of measurements and numerical points of

reference: The moments of the day and year are placed under the sign of specific symbols and representations, be they associated with work, feasting, rituals, or politics (Zerubavel 1987).

Finally, the production and reception of knowledge about 'time' as a pure social construct is probably the ontological layer that is the most dependent on our imaginative abilities. A qualitative dimension is awarded to some specific moments without any relation to biophysical reality, such as weekend, break, free time, or leisure. One of the ways in which imagination operates is through storytelling. Narratives about the past and future, and their interrelation, shape our vision of time. By and large, artists play an important role in shaping our time imagination. As far as sustainability is concerned, the ideas of progress, collapse, apocalypse, resilience, transition and so on have inspired numerous artists, thus shaping our mental representations.

Time planned

Finally, as with space, time can also be planned. In this perspective, time is not seen as a tool or a means for planning, but planning is deemed a way to develop knowledge about time. In brief, planning is a process of knowledge production involving activities of sequencing, organizing, evaluating, ordering, and dividing. Thus, it is an institutional activity that requires collective rules and methodologies and a specific production context.

Time planned draws close to the concept of 'time maps'. Coined by Eviatar Zerubavel (2003) to analyze the social shaping of the past and collective memory, this concept was later applied to the study of future-oriented projections in societies. 'They provide a cognitive line or surface on which both past events and anticipated future events can be emplotted into a narrative' (Snyder 2019, 649).

Planning time is first and foremost a type of epistemology used in the sociocultural realm (i.e., time and 'time' layers). The social production and reception of time often entail sequencing and ordering. Historians and archeologists typically gather descriptive and contextual data, along with evidence from the past, and organize these around specific divisions, be it ages (golden, silver, bronze), eras, or cycles, for instance. The planning of time also focuses on shaping the future, with activities such as anticipation or predictions. Backcasting, a method for building future scenarios in a specific sector (e.g., energy, water management ...) and then moving backwards in time step by step to plan changes in the present, is commonly used to envision sustainable strategies. In the case of climate change, Lockie (2014) showed that the temporality embodied in scenarios building has generated a prioritization of mitigation over adaptation and tended to postpone the actions needed for other

disruptions to Earth-system processes such as biodiversity loss.

As far as the third layer is concerned, the work of Dale Southerton (2006) illustrates the planning of 'time'. He studied the temporal organization of practices in daily life, such as their temporal rhythm, namely their periodicity, sequencing, duration, tempo, synchronization, and coordination. The allocation of practices to specific time slots is affected by socio-demographic factors such as gender, age, life-course or education but, also, by the social construction of 'time' (e.g., significant differences between week and weekend).

Discussion: potential implications to overcome temporal epistemic barriers

In this paper, I have suggested a new analytical framework as an original input for the socio-ecological theorization of time thereby linking the relational realism of Carolan with ecological Marxism of Lefebvre. I believe this association make sense to deepen the understanding of the epistemological dimension of the original stratification framework. It is worth noting that Stuart (2016) explained how ecological Marxism could be beneficial to broaden the research scope of the social-biophysical stratification framework, especially when it comes to include power relationships or understand the ideologies behind the structural drivers of environmental degradation.

Coming back to my research question, in this section I will discuss the potential implications of my analytical framework to overcome epistemic barriers related to temporality thereby opening new avenues for interdisciplinary research and environmental governance. Due to space constraints, I will mainly develop two inputs: the first one being related to time ontology and the second to time epistemology.

First, one key and longstanding epistemic barrier to sustainability has been to ignore or downplay the multiple and complex temporalities of earth-system processes and their interlinkage with the sociocultural realm. Yet understanding their uniqueness is critical to face environmental threats. In social sciences, 'natural time' was often considered either as an unquestioned background condition or as 'largely immutable'. Bringing time into the social-biophysical stratification framework is useful to clarify the complexity of time's ontology. Despite its influence on modern societies, the absolute and abstract definition of time, often defined as 'clock time', is only partially representing time's reality. As Lockie & Wong put it, 'while abstracted notions of absolute time and space facilitate the coordination and commodification of human activity, they cannot abstract those activities from their material conditions and consequences. As the Anthropocene proposition reminds us, all economic

and social activity is embedded in Earth-system processes that lie within our sphere of influence but outside our sphere of control.' (Lockie and Wong 2018, 332). The social-biophysical stratification of time framework acknowledges the differences between so-called 'natural time' and 'social time' linked with the specificities of the temporal features of the processes at stake in each of the three strata. Newton (2003) noted that temporality, especially pace, was a key factor to differentiate the strata in a critical realist perspective: the real is being characterized by its longevity as opposed to the fast pace and transitive knowledge of the empirical and the actual. The risk of this perspective is to fall into the trap of assuming that epistemological position is determined by temporality. The aim of the analytical framework developed in this paper is to contribute tackling so-called 'wicked environmental problems' such as nuclear waste or climate breakdown which necessitate to work simultaneously across the temporalities of three strata and their mutual relationships.

The second input of the analytical framework is to address the complexities related to time epistemologies. Indeed, if we want to overcome the epistemic barriers linked with temporality, the first step is to deepen our critical stance on the various mechanisms of social production and reception of knowledge about time as well as on the temporality embodied in knowledge practices at the core of sustainability strategies. Three fruitful research avenues could be pursued. First, it would be important to analyze the respective influence of the dimensions of knowledge production and reception around time such as the subjective/institutional or contextualized/decontextualized. The literature focuses either on the subjective or the institutional standpoint but without necessarily connecting the two. For instance, on a subjective and contextualized standpoint, studying corn farmer's reactions to climate change in US Midwest, Houser, Stuart, and Carolan (2017) showed that 'seeing is not always believing'. In an institutional and decontextualized standpoint, Lockie (2014) studied how the temporality embodied in knowledge practices such as climate change scenarios could influence the strategies, such as the prioritization of mitigation over adaptation.

Second, it would be interesting to investigate the power relationships between the various time epistemologies. It seems that the temporality of dominant socio-political conventions and knowledge practices around sustainability strategies rely mostly on two epistemologies: *time conceived* and *time planned*. Yet, scholars agree that 'conceiving' (through education and information) is not always the best strategy to overcome epistemic barriers to sustainable practices. On the one hand, many researchers and artists are convinced of the necessity to develop realist and

engaging narratives about the future. Subjective and contextualized type of knowledge involving not only cognition but also emotions, the body, and relationships with specific places. In order to create social awareness and support, *time conceived* needs to be made flesh and blood, entering into a dialogue with *time imagined*. Some scholars have started to investigate how alternative cultural conceptions of time could renew the Western epistemology of time and influence our understanding of sustainability (e.g., Winter 2020). On the other hand, at the level of the empirical, we will also need to work on *time perception* to foster awareness of, and support for sustainability issues as well as their contextualization. The past forty years have proven that a broad scientific consensus around major sustainability issues – such as climate breakdown – is not enough to trigger the drastic changes needed in society. The risk associated with the domination of *time conceived* is epistemic distance (Carolan 2006). For the related knowledge seems abstract, distant, and difficult to fully grasp. Finally, it would be worth deepening the relationships between the ontology and epistemology of time, such as investigating the mediating role of the body and technical devices to access the biophysical dimension of sustainability issues.

Conclusion

At the core of environmental sociology as a sub-discipline is the call on social sciences for 'bringing nature back in' (see, for instance the seminal article by Catton and Dunlap 1978). Scholars who developed a socio-ecological theorization of time have been calling for 'bringing time back in' the equation. As Adam puts it

"nature, the environment and sustainability, are not merely matters of space but fundamentally temporal realms, processes and concepts. Their temporality, furthermore, is far from simple and singular. It is multi-dimensional, a multiplex aspect of earthly existence. Without a deep knowledge of this temporal complexity, I suggest, environmental action and policy is bound to run aground, unable to lift itself from the spatial deadend of its own making." (Adam 1998, 8)

New analytical insights are needed to open up the discussion on classical distinction related to time and the environment. In the realist-constructivist debate, the ontology of time is mostly treated as an opposition between 'objective' (i.e. independent, exogenous) and 'subjective' (i.e., dependent, socially constructed and culturally mediated) realities. I have argued that this dichotomy is misguided for two reasons.

On the one hand, it confuses the *ontological* and *epistemological* dimensions of time. The first step is to make a clear distinction between the investigation of the reality of time and our knowledge claims about this

reality. This conceptual distinction helps us gain analytical insights as well as opening new research avenues. The analysis should not only deal with human beings and their relationship to time, but also with the specific temporality of biophysical processes in their interlinkage with the multiple temporalities of social processes. What is more, it triggers a discussion on the variety of time epistemologies, which are more complex than the sole objective-subjective axis.

Highlighting two major dimensions of knowledge production around time (institutional-subjective and contextualized-decontextualized), a conceptual typology based on a temporal epistemological quartet was set forth: *time conceived, imagined, perceived and planned*. The relationships between the ontology and epistemology of time open new research avenues such as investigation the power relationships between the different social production and reception of knowledge about time or the potential of new strategies based on the articulation of various time epistemologies.

On the other hand, the dichotomy between 'natural time' and 'social time' needs to be reconsidered as they are neither two separate entities nor equivalent. The assumption in this paper is that the sociocultural and the biophysical realms are indeed mutually constitutive. Applying a relational realist perspective to study the ontology of time is fruitful because it reveals the dynamic and interpenetrating relationships between various layers of time (Time-time-'time'). It also highlights the ontological asymmetry between the biophysical and the sociocultural realms.

Most individuals and organizations still overlook the specific temporal and spatial features of material aspects of the environment and the complex ways they are inter-related with socio-cultural phenomena. However, an ecological ethics is only possible if we retain an analytical distinction between those two realms and differentiate humans from more-than-humans. An ethics of strong sustainability is first and foremost the recognition of planetary boundaries for a range of Earth-system processes and our responsibility to set some limits and conform to them. Human beings have indeed the unique ability to integrate past experiences and future preoccupations in the present moment, as well as to develop a critical stance on their own knowledge practices. Our ability to develop time reflexivity and time agency will be key in our efforts to tackle disastrous environmental changes.

Notes

1. Time has been the subject of a longstanding preoccupation in sociology (and social sciences more broadly). However, it did not emerge as a specific sociological sub-discipline before the 1970s. For a literature review related to the major themes in sociology of time see, for instance, (Bergmann 1992).

2. Temporality is nevertheless central in the critical realist approach. Newton (2003) explained the centrality of pace to make the difference between the three strata.
3. For a systematic discussion of Henri Lefebvre's work, see (Elden 2004). The fifth chapter is dedicated to a discussion of his writings on time and space. For a presentation of Lefebvre's contribution to environmental sociology see (Foster et al. 2020)
4. In his book, Lefebvre refers more explicitly to the concepts 'spatial practice' (perceived space), 'representations of space' (conceived space), and 'representational space' (lived space) (Lefebvre 1992; [1974], 38). Finding this designation confusing, I chose to refer to the core elements of their definitions.

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