INTRODUZIONE

Time and the Continuum. An Introduction to the Problem(s)*

Marcello Garibbo
University of Siegen

Marcello Garibbo is a PhD student at the University of Siegen. In his PhD project, Marcelloinvestigates the temporal structure of perception and experience in the philosophy of Kant.

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Philosophy in the 20th Century is usually characterized in terms of the linguistic turn, language being a central topic that cuts across very different philosophical schools (Continental vs Analytic, Phenomenology/Hermeneutic vs Structuralism and Post-Structuralism, etc.). Yet, looking at its major philosophical, scientific and literal works, we may as well speak of a *temporal turn* to describe the movement of thinking throughout the century. From Bergson's *Creative Evolution* to Heidegger's *Being and Time*, from Einstein's theories of relativity to Prior's temporal logic, from Proust to Borges, the engagement with time is ubiquitous from the beginning to the end of the Century, tracing an alternative line of thought that runs parallel to that of the engagement with language. And, in fact, this line becomes even more visible and important now, from the perspective of the 21st Century where the linguistic turn seems to have been put aside and the topic of time is even more on the rise. In the last years, publications on the topic have been literally exploding, not just in metaphysics and philosophy of science, but also in the philosophy of mind, the philosophy of action, in ethics, and aesthetics.

This raising interest in the topic of time may have one of its important roots in the pervasive feeling that contemporary life has a serious problem with time, having made this the scarcest of all resources. Already Heidegger complained against the fact that the rhythm of modern life is dictated by a permanent lack of time (Heidegger 1983, 115). Over the course of the last century and especially towards the end, through the digital revolution, this experience has been pushed to an extreme. Recurrent talk of acceleration, of temporal disintegration, and of dysinchronicity testify to the fact that something has changed drastically in our relationship to time, creating a sense of loss and impotence. [1] Traditional ways of experiencing, thinking, and organizing time that held for centuries seem no longer available. The result is that we feel as much disconnected from the past as we do from the present and the future. We have been long shipwrecking in the raging river of modern times. Given

1 Many different works have explored the way our experience of time has changed over the last century. Two recent examples are Rosa (2015) and Han (2017).

this permeating feeling that we have somehow lost time, it is not surprising that so many philosophical works engages with such topic. As if the loss could be somehow compensated by thinking and the raging river be brought to rest in the vast number of books and publications on the topic.

Metaphors besides, re-thinking time and our relation to it seem to have become a matter of both theoretical and practical necessity. And the relation between time and the continuum is particularly relevant here. Then, as philosopher Byung-Chul Han points out, contemporary life is characterized by an ineradicable discontinuity (Han 2017). The 20th century has experienced the radical break from the past as well as the decline of utopian visions of the future. This has left us with an isolated present with no great temporal breath. Moreover, such discontinuity does not only shape the experience of history, it is also entrenched in our everyday life. Due to the strict regimentation of work and leisure, we often seem to experience *our* time as a sequence of disconnected events, appointments and achievements. This leaves little space for temporal breath, thus for an experience of duration. It makes any form of dwelling, resting and lingering difficult. [2] Precisely in the light of such developments, it appears particularly relevant to reflect upon the concept of *temporal continuity*. What does it mean for time to be continuous? Does the passage of time imply some sort of continuity that holds past, present and future together? Or, is time really just a sequence of disconnected events? In fact, developing the right concept of temporal continuity is a necessary condition for understanding any experience of duration and persistence, hence for thinking (and re-thinking) our relationship to time.

2 Codermatz's contribution to this issue analyses how psychological disorders such as schizophrenia are intimately related to a discontinuous experience of time.

From a purely theoretical perspective, the concept of *temporal continuity* is problematic mainly for one reason. In contrast to space, time is intimately connected to change and appears therefore irreducibly dynamical. Temporal change seem to imply more than the simple distribution of difference in a pre-given space. It seems to imply a genuine coming-to-be and a genuine passing-by. This raises a fundamental question: How can time be conceived as being both something continuous, hence extensive, and passing?

The current issue of Philosophy Kitchen investigates the notion of **temporal continuity** by grappling with these questions from a genuine philosophical perspective. We do not think that such questions can be settled by mathematical theories of the continuum or by physical notions of time alone. They require philosophical reflection about the way we experience time and we think of ourselves in the world. Only by addressing these questions at this level can we make *sense* of our experience and thus rethink our relationship to time.

More specifically, the aim of the issue is to show the relevance of the topic of the temporal continuity for the contemporary philosophy of time in its different strands. Especially in the context of analytic philosophy of time, the orthodoxy is to presuppose a mathematical conception of the continuum that goes back to Georg Cantor. Whether such a conception is apt to capture the nature of time is hardly discussed. Thus, the issue wants to bring to attention some problems that such conception may lead to. It wants to discuss possible solutions as well as considering alternative conceptions of the continuum from the history of philosophy and mathematics which may be better apt to capture the dynamical nature of time.

In what follows I'll first sketch some important stages in the history of the concept of the continuum to show how the contemporary orthodoxy to think about continuity emerged. The second part discusses the continuum in relationship to time.

I'll point at some questions the Cantorean definition of continuity raises in connection to three different debates in the philosophy of time: the nature of temporal passage, the meaning of temporal existence, and the ontological status of processes. This will provide some background for the papers published in this issue, as well as giving a general motivation for why the question about temporal continuity is of crucial importance.

I. The Continuum: A Brief History of the Concept

The concept of the Continuum has a very long history, going back to Zeno's paradoxes, hence to the very origin of western philosophy. From then onward, the problems that Zeno's paradoxes raised have been discussed in very different forms by philosophy, mathematics, and the natural science. Whereas mathematicians focused on the continuum to develop a formal definition of the real numbers, scientists addressed Zeno's paradoxes in the context of a treatment of movement, time and space. Philosophers grappled with both approaches, trying to reflect on their ontological and metaphysical implications.This variety of different perspectives and questions makes it very difficult, in fact impossible, to trace a single history of the concept. We may rather speak of histories of the Continuum, some of which are interconnected, others which remain independent of one another.

In the light of such a plurality of histories, here I will concentrate on a few important moments that allow for telling one consistent narrative about the development of the concept, a narrative that is in no way exhausting or inescapable. This narrative will mainly concern the abstract concept of the Continuum, independently of whether the continuity of space, time, or change is at issue.

The first important stage in this history of the concept is Aristotle's engagement with Zeno's paradoxes of motion in the Physics. Zeno had tried to demonstrate the non-existence of motion by showing that it-can be neither infinitely nor finitely divisible. [3] To avoid Zeno's conclusion, Aristotle developed a detailed analysis of the notion of continuity. Central to this analysis is a top-down approach according to which the continuum is an undivided whole given prior to its (possible) parts. For Aristotle, parts merely are the result of a process of dividing that can be repeated *ad infinitum* (*Phy*. 231b15). From this, Aristotle inferred that indivisible points are neither actual nor potential parts of the continuum. However often the continuum is divided, the process of division never leads to points. Since all potential parts of the continuum exist only as a result of a process of division, points cannot be parts of the continuum. Points exist only as potential boundaries of continuous parts. They do not have any independent existence. [4] When applied to time, Aristotle's understanding of the continuum has many consequences. Is time continuous, so it follows that no temporal instant has an immediate successor. For, instants only exist as boundaries of temporal intervals. Accordingly, time is understood as that which passes continuously between any two instants, not as a sequence of extensionless instants. [5]

This conception of the continuum together with Aristotle's understanding of the infinite have set the framework for all later developments of the

3 Zeno's paradoxes have only survived in Aristotle's formulation in the Physics. See Aristotle Phy, 239b-240a. For a general discussion of the paradoxes, see the contributions in Salmon (1970).

4 A classical interpretation of Aristotle's account of continuity is Wieland (1962, 278-325). For a more recent analysis of this account in comparison with contemporary mathematics, see White (1994).

5 This particular understanding of continuity leads to a series of puzzles about the nature and the status of time, which Aristotle attempts to solve in Book 4 of the Physics. See Coope (2008) for a recent interpretation of Aristotle's solution sensitive to the issue of continuity.

concept. In the 14th Century, Aristotle's conception of the continuum became object of an intensive debate. William of Ockham proposed a view of the continuum that in some respects departed from the Aristotelian view and anticipated later mathematical developments. [6] Thomas Bradwardine argued at length for the Aristotelian thesis that continua could not be made out of indivisible parts (see Bell 2013). Furthermore, in the 15th Century, Nicholas of Cues developed an account of the actual infinite which became prominent in the later mathematical description of the continuum by Cantorean set theory (see Moore 1990, 55-56).With the rise of modern science and the invention of the differential calculus, discussions about the continuum took a new turn. Developed independently by Newton and Leibniz, the calculus allowed the calculation of instantaneous quantities such as velocity by making use of infinitesimals. These are infinitely small quantities and therefore presuppose a conception of the actual infinite. Moreover, they make possible a new understanding of the continuum where it is constituted of infinitely small indivisible sections. For this reason, their introduction was an important step towards the abandonment of the Aristotelian framework and became the subject of numerous controversies. [7] It was only with the birth of set-theory at the end of the 19th Century that these controversies were (partly) resolved, as a formal treatment of the actual infinite put forward by Cantor.

6 For a reconstruction of Ockham's view, see Roques (2017a). See also Roques (2017b) and Bell (2013, Sec. 3).

7 For a good discussion of the calculus in connection with both the infinite and the continuum, see Moore (1990, 57-74).

During the 18th, Immanuel Kant's understanding of the Continuum is still essentially Aristotelian. Like Aristotle Kant considered continuous magnitudes to have extended parts only, points being no parts of continua but only limits (Kant 1781/87, A169/B211). He did not break with such a definition, as later mathematician would do. Nonetheless, Kant still represents an important point within the history of the Continuum. For, Kant related the continuity of space and time to their being *intuitions* rather than concepts. According to the arguments of the Transcendental Aesthetics in the *Critique of Pure Reason,* the continuous nature of space and time is nothing that can be grasped on conceptual grounds alone. It requires an intuition, a singular immediate presentation of its object (Kant 1781/87, A32/B47). Thus, Kant established an important distinction between intuitional and formal/conceptual accounts of the Continuum, which would be later taken up by different philosophers and mathematicians in reacting to Cantor. [8]

8 In the context of Kant's understanding of the Continuum it is important to mention the works of Gerold Prauss. Prauss argues that Kant's understanding of time presents elements of a radically new conception of continuity (Prauss 2001). Starting from Kant, Prauss works out such a conception, criticizing both Aristotle's and Cantor's definition. See Prauss (2017).

It is difficult to overestimate the importance of the works of Georg Cantor at the end of the 19th Century. At least from a mathematical perspective, these present the most important development in the history of the Continuum since Aristotle, set theory having become the foundation for doing and understanding modern mathematics and physics. However, not only because of this are such works philosophically relevant. They also have led to a radically new way of thinking about infinity and the Continuum.

In a nutshell, Cantor's account is based on the identification of the Continuum with the structure of the real numbers. According to this identification, the set of the real numbers is isomorphic to the set of potential points of dividing a line in space. Thus, the Continuum is no longer seen as an irreducible concept, but it is identified with a certain set of *points*. Cantor developed a definition of such a set through a

formal construction of the reals. [9] These constructions deliver a purely algebraic definition of a continuous line freed from any geometric intuition. This definition requires the concept of the actual infinite developed by Cantor's theory of transfinite numbers. Thanks to this, the continuum could be identified with an actual (uncountable) infinity of points satisfying certain properties (see Moore 1990, 110-122). This new approach to the continuum breaks radically from the Aristotelian understanding of both the continuum and the infinite, as well as from our everyday intuition. For this reason, it received numerous critiques from philosophers and mathematicians at the beginning of the 20th Century. The pragmatist philosopher and logician C.S. Peirce defended an Aristotelian approach of the Continuum against the set-theoretic one (Peirce 1992). Similarly, the mathematician L.E.J. Brouwer took the intuition of the temporal continuum as the basis for a constructivist account of real numbers (Brouwer 1975). Herman Weyl argued for the impossibility of any formal definition of the Continuum to match entirely with our intuitions (Weyl 1987).

9 Cantor constructed the reals by using fundamental sequences, whereas Dedekind developed a more intuitive construction based on so-called Dedekind's cuts. See Bell (2013).

Parallel to this controversy in the context of the foundation of mathematics, the beginning of the 20th Century saw the rise of phenomenology. Edmund Husserl engaged directly with the Cantorean set-theoretic account of the Continuum. His phenomenological approach led him to emphasize the priority of an intuitive account of the Continuum over any formal, mathematical treatment of it. [10] Thus, Husserl followed Kant in emphasizing a dichotomy between intuitional and conceptual accounts of the continuum. Moreover, Husserl argued for the phenomenological fundamentality of time, thus ascribing a central role to temporal continuity in the constitution of intentionality. Another important thinker of the beginning of the 20th Century is Henri Bergson. Bergson did not only insist on the profound differences between our intuition of the continuum and any conceptual description of it but also emphasized the dynamic nature of time. On this basis, he rejected any attempt to model the continuity of time with a spatial line. Independently of whether such a line is given through geometrical intuition or described conceptually, it is static. It is therefore not suitable for understanding the continuity of time. By the notion of a qualitative multiplicity, Bergson tried to develop an alternative conception of the Continuum to reconcile the dynamical nature of time with its continuity. [11] Given that the distinction between temporal and spatial continuity is a recurring topic in this issue, this makes Bergson particularly relevant. [12]

10 For a discussion of Husserl's engagement with Cantor and of his understanding of the Continuum, see Tarditi's contribution to this volume.

11 As above suggested, such a distinction can be already found in Kant. Even Aristotle in some passages of the Physics seems to suggest that there may be crucial differences between temporal and spatial continuity, see the Interview with Tom Crowther in this volume. For a comparison between Bergson and Aristotle's conception of time, see de Lándazuri's contribution to this issue.

Despite these controversies, during the 20th Century Cantor's account of the Continuum became the standard framework to think about continuity. This holds not just for the continuity of space, which was the focus of Cantor's works, but also for the continuity of time and change. Motivated by a general skepticism towards intuition, the rise of formal methods in mathematics, philosophy and physics certainly contributed to the establishment of such a framework. Cantor's definition of the Continuum delivered a solution to Zeno's paradoxes that was formally correct and therefore, as many philosophers argued, satisfactory.

12 In this context it is also important to mention the works of William James and Alfred North Whitehead. James' conception of the stream of consciousness ascribed a central role to temporal continuity. See James (1981, 148) where James introduced the concept. See also James

II. The Continuum and the Contemporary Philosophy of Time

At this stage we can now turn to the specific question of temporal continuity. How should the continuity of time be understood? As I have suggested above, the orthodoxy in the contemporary philosophy of time is to take Cantor's definition for granted. [13] Even if Cantor's original intent was to develop an algebraic equivalent of the spatial continuum, his identification of the continuum with the set of the real numbers can be and has been applied to time. To do this, it is necessary to map the real numbers with instants of time. The total order on R given by "<" corresponds to the order of temporal instants according to the relation of "before-than". [14] Density here means that each interval of time can be further partitioned into smaller intervals. Lastly completeness means that each instant of time represents the common boundary of past and future. In this section I want to show that such an assumption is problematic and therefore requires further discussion. To do so, I will focus on three debates in analytic philosophy related to time. The claim is going to be that the Cantorean definition of the Continuum raises a series of questions, at least for those views which emphasize the dynamic nature of time.

(1930, 181-3) where James explicitly engages with Cantor's conception of the continuum. On the other hand, Whitehead denied the continuity of becoming on the basis of Zeno's paradoxes. He famously argued that «There is a becoming of continuity, but no continuity of becoming». (Whitehead 1978, 35).

13 The application of Cantor's definition of the continuum to time goes back to Russell (1914) and has been developed systematically in Grünbaum (1973).

14 One does not need to apply this to a universal order. The model can also be applied within the context of the Theory of Relativity. In this case, it suffices to identify a local ordering of events along a world-line. See for instance Grünbaum (1973), 326-8).

The first important debate in the contemporary philosophy of time concerns the question about the fundamentality of temporal becoming and goes back to McTaggart's distinction between two series of time (see McTaggart 1909). The A-series determined by past, present and future, the B-series determined by the binary relations after-than, before-than and simultaneous-with. Based on this distinction, the A-Theory argues that the A-series marks fundamental aspects of reality. *Tensed* temporal determinations such as "present", "past" and "future" relate to aspects of the world which are fundamental and thus irreducible. This implies a commitment to the reality of temporal becoming. Time passes in a way which differs radically from the distribution of difference in space. It implies things becoming present. [15] In contrast to the A-Theory, the B-Theory rejects the fundamentality of the A-Series. According to the B-Theory. The tensed determinations are considered as merely indexical linguistic devices through which we relate to a tenseless world. They do not pick out real properties of things but rather reflect our subjective perspective on the world.

15 The standard formulation of the eternalist (new) B-Theory of Time goes back to Mellor (1998). For a defence of the Moving Spotlight Theory (MST) see Deasy (2015) as well as Marques' contribution to this volume; for the Growing Block Theory (GBT), see Correia & Rosenkranz (2018); at last, for presentism see, e.g. Friebe (2012). For an overall view of the debate see Fischer (2013).

The second debate is intimately related to the first one, it concerns the notion of temporal existence. How precisely such debate should be understood is a matter of numerous controversies. [16] As a first approximation, it can be understood as addressing the following question: What kind of things exists? Do past and future things exist? Eternalism is the view according to which to exist in time is to be located at

16 In the last few years, some authors call for a reformulation of the controversy in terms of the distinction between *permanentism* and *temporarysm*. (Williamson, 2013; Deasy, 2017; Correia/ Rosenkranz 2018). Here I will stick to the traditional formulation.

some instant of the entire spatio-temporal block. Thus, according to eternalists past and future things exist as much as present things do. On the other hand, presentism emphasizes the relation between *existence* and *presentness*. Thus, presentists hold that only present objects exist. Insofar as "present" is a tensed expression, presentism presupposes the A-Theory of time. While the A-Theory assumes that the present is a fundamental aspect of reality, presentism specififfies such fundamentality in ontological terms. The fundamentality of the present is the fundamentality of existence. Further views in the debate are the growing block theory, according to which the present and the past equally exist and the moving spotlight theory, which combines eternalism with an A-Theory of time.

The claims concerning temporal continuity apply to permanentism and temporaryism as well.

In the light of these two debates, Cantor's definition of the Continuum raises a series of question. First, it is not clear how this understanding of the Continuum could be compatible with presentism. [17] Insofar as it presupposes an actual infinite of distinct temporal points, the Cantor's Continuum seems to imply a commitment to eternalism. [18] Moreover, the model only describes the continuity of *temporal order*. It leaves out any sense in which temporal becoming as the motion/direction of the present may be continuous. Hence, the challenge of reconciling this model with the dynamical nature of time seems to hold for any A-Theory. [19] Different alternatives are open. One may argue that dynamic theories of time such as Presentism should develop a different understanding of temporal continuity, thus the importance of looking at the history of philosophy and mathematics for alternative conceptions of the Continuum. Another possibility here would be to reject temporal continuity *in toto* by claiming that time is not continuous. Some recent developments in physics seem to point in this direction. [20] This nonetheless raises a series of further questions concerning the extension of the present and its elapse. [21] Moreover, it is not clear how the physical discreteness of time should be addressed philosophically. Even if physical time consists of indivisible temporal intervals, dynamic theories could still be arguing that time passes within such intervals. The third important debate does not concern time as such but a specific class of temporal entities, namely processes. A lot of work has been recently devoted to the logic of aspects and to the difference between the progressive and the perfective.

17 Bourne (2009) is an example of a presentist who presupposes Cantor's definition of the Continuum (see for instance p. 55).

18 In fact, it presupposes an uncountable infinity of points corresponding to the cardinality of the real numbers. That the infinity is uncountable is however not relevant here. The central problem is that continuity is understood as a property of a set that has more than *one* point.

19 Both Friebe and Yechimovitz argue in this volume that the Growing Block Theory of Time has a problem with temporal continuity. In contrast, Orilia presents a version of presentism called *substantivalist presentism* that is compatible with Cantor's definition of continuity.

20 Rovelli argues for the discreteness of time on the basis of recent developments in Quantum Mechanics, see Rovelli (2018).

21 For a discussion of such questions and problems see Craig (2000, 227-248).

Consider for instance the sentence in the progressive: "Marcel is writing his last book". Such sentence describes an occurrence as it is unfolding. In contrast, the sentence in the corresponding perfective form "Marcel has written his last book" describes an action in the past that has come to an end. It is possible for the sentence in the progressive to be true without the sentence in the perfective ever being true. Marcel may be writing his last book without ever the complete event of Marcel's writing of his last book been instantiated. Marcel's writing of his last book could be

interrupted, for instance by his sudden death.

Reflection on similar examples has led some philosophers to draw an important distinction between events and processes. [22] In contrast to spatio-temporally bounded events, processes are understood as incomplete, extending temporal entities. They are the ontological correspondent to the linguistic progressive aspect. This in turn means that processes are essentially continuous. Their unfolding is continuous in the sense of being always further extendable and at any point divisible. However, it is hard to see how the Cantorean conception of the Continuum could help understand this kind of continuity. Such an understanding presupposes then an actually infinite set of points, thus it describes a structure that is devoid of any incompleteness. [23] Hence, a different understanding of temporal continuity may here help to shed light on the nature of processes.All these considerations lead to the fundamental question of the volume: How can time be conceived simultaneously as something continuous, hence extensive, and passing? They suggest that this question cannot be settled by appealing to Cantor's formal definition of the Continuum alone. Be it in the context of the debate about temporal passage, about temporal existence or about the ontological status of change, views which hold onto some robust sense of becoming seem all to be requiring a more dynamic account of the continuity of time that is not delivered by Cantor's.

22 For a systematic study of the logic of aspects see Galton (1984). Thompson (2008) has emphasized the importance of such distinction for action theory. O'Schaugnessy (2000) and Soteriou (2018) do the same for the philosophy of mind. They argue that experience is a process, by necessity. There are different ways in which the ontological status processes can be understood, see Stout (2016) and Crowther (2018) for two opposing views.

23 In discussions about *processes* and the progressive, Aristotle's definition of the continuum has been recently rediscovered. See for instance Rödl (2005, 166-172) and Arsenijevic (2007). A further, here related issue concerns the problem of the first moment of change. This problem arises when one considers the beginning of change and is therefore intimately related with the continuity of time and change. See Strobach (1998) for a systematic history of such problem as well as Fischer's contribution to this volume, where dispositions and processes are introduced to solve the problem.

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I. ELEMENTI STORICI /HISTORICAL PERSPECTIVES