Reichenbach on Space and Time

Arto Siitonen, Helsinki, Finland

Introduction

In the German book market, the year 1920 brought a rich harvest of works dedicated to the problems of space and time in the context of relativity theory. Albert Einstein's *Über die spezielle und allgemeine Relativitätstheorie* was published in the 6th edition and Moritz Schlick's *Raum und Zeit in der gegenwärtigen Physik* in the 3rd edition; Hans Reichenbach's *Relativitätstheorie und Erkenntnis a priori* appeared. Moreover, a year later, Ernst Cassirer's *Zur Einsteinschen Relativitätstheorie* appeared. The theory of relativity had been on the agenda since 1905, and philosophical discussion on its presuppositions and implications was now expanding.

Reichenbach had been Cassirer's pupil in Berlin during the academic years 1911 - 12 and 1913 - 14. As the name of his book indicates, he tried to reconcile the Kantian heritage with the method and results of relativity theory. To the latter, he had a first-rate access as a pupil of Einstein. Einstein gave the first course on his theories at the university of Berlin during the winter term 1918 - 1919. The lecture room was not exactly crowded: there were at most five participating students, one of whom was Reichenbach. He had published his doctoral dissertation in 1915 and was working in radio industry as a laboratory physicist. (Cf. Gerner 1997)

Reichenbach says that Schlick's aforementioned book gives a "good presentation of the physical content of the theory" (English translation of Reichenbach 1920, 1965, 110). He adopted the ideas of implicit definition and of knowledge as coordination (*Zuordnung*) from Schlick's 1918 book, *Allgemeine Erkenntnislehre*. (Cf. Schlick 1979, section 7, p. 49 - 57); Reichenbach 1920, 33 f, and Schlick 1979, 40, 78 ff; Reichenbach 1920, 34 ff). Concerning Cassirer's 1921 book, Reichenbach says: "The work is intended to furnish the basis for a discussion between physicists and philosophers. Indeed, nobody seems to be better qualified in the Neo-Kantian camp to start such a discussion than Cassirer, whose critical analysis of physical concepts has always tended in a direction familiar to the theory of relativity. This is especially true for the concept of substance." (1965, note 20, 114). At this point Reichenbach mentions Cassirer's work on the concepts of substance and function, which had appeared in 1910. In his own work, Reichenbach's analysis of the concept of substance was so thorough as to be dissolving.

Reichenbach adds to the above-cited remark: "Unfortunately I could not consider Cassirer's contributions, for I was able to read them only after this book had gone to press." (1965, note 20, 115). Cassirer in 1921 gives a corresponding message concerning Reichenbach's text: he had received its manuscript only when his own book was already in press. He praises Reichenbach's work for its sharpness and thoroughness but does not fully agree with its results, especially those concerning the relationship of relativity theory to Kant's epistemology. (Cf. Cassirer 1994, 125).

Reichenbach's book is a compromise between the claims of Kantianism and Einstein's relativization of space and time. In his dissertation, Reichenbach had defended the thesis that mathematical presentation of reality requires probability as a complementary category to causality, the term 'category' understood in the sense of Kant. This (even more than) full-blown Kantianism was challenged by Einstein's theories. Reichenbach managed to preserve the general principle of coordination as the *a priori* valid condition of experience. However, partly under the pressure of problems and partly under the influence of Schlick, he headed towards empiricism, which became visible in his book on the axiomatic foundations of the theory of relativity (1924). In his third work on the problems of space and time, *Philosophie der Raum-Zeit-Lehre* (1928), Reichenbach has a thoroughly empiricistic standpoint.

Reichenbach's trilogy signifies a modification of the traditional ideas; he rejects the Kantian critique of pure reason for a science-based critique of space, time, substantiality and causality. Kant's twin questions concerning phenomenal space and phenomenal time give way to the questions of defining the proper geometry for physical space and of defining the adequate chronometry for physical time. In his study of the order of time, Reichenbach was led to the question concerning the direction of time. In his last book, he supplemented what he had learned from Einstein with his studies of Ludwig Boltzmann's thermodynamics. He also profited from his own early research on the problem of probability.

Below, Reichenbach's views on the problems of space and time will be analysed. After that, questions concerning the relation between time and history will be raised.

1. Relativization of Space and Time

Isaac Newton presented an absolute theory of space and time, which was challenged by Leibniz's relational theory. According to Newton, space and time are reservoirs that contain all occurrences and things; according to Leibniz, space and time are sets of relations between things and between occurrences. The relational theory was developed by Ernst Mach and mathematized by Einstein in the form of his special theory of relativity in 1905 and his general theory of relativity in 1916. Accrding to Einstein's theories, spatial distance, time intervals and mass depend upon the particular frame of reference in which they occur and can be measured. (Cf. Einstein 1918).

In the same year as that in which his basic article on the general theory appeared, Einstein also published his above-mentioned book on the special and general theory of relativity (first edition 1916, third 1918, sixth 1920). Two years later he was lecturing about his theories in Berlin, where the then 27 years old physicist and philosopher Hans Reichenbach became his pupil. Reichenbach described the problem with which he was confronted due to Einstein's course as follows: "...either the theory of relativity is false, or Kant's philosophy needs to be modified in those parts which contradict Einstein" (1965, 4). Since to seize the first horn of the dilemma seemed unpromising, he chose the second one of developing a constructive philosophy alongside a continuing critique of Kant's system, thus paving the way for a life-long task.

Reichenbach explicates the ideas of new physics and studies their clash with traditional conceptions. The general theory of relativity claims that physical space is not Euclidean, whereas according to Kant, the Euclidean character of space is an *a priori* principle. Kant's method was the analysis of reason, but Reichenbach replaces it with the analysis of science. Kant considered space and time to be forms of intuition, whereas according to Reichenbach, on the one hand, they are part of the conceptual machinery of science and on the other hand, they are objective properties of the world. In a certain sense, Kant's theory of knowledge has been refuted by experience. However, the concept of *a priori*, in a modified sense, is confirmed by relativity theory: the principles that determine the coordination of facts to equations have a basic role in the logical structure of knowledge. They define what knowledge is and what is knowable. They are the answer to the Kantian question, 'How is knowledge possible?'

This was Reichenbach's position in 1920. Later he would study the historical roots of relativistic standpoints in Leibniz' and Mach's theories, and would analyse the conceptual structure of relativity theory without any commitment to Kantianism. According to him, the questions concerning the nature of space and time can be fruitfully treated through investigation of the measurement of distances and processes. The proper equipment for spatial and temporal measurement are rods and clocks, which are to be understood in a broad sense. They include any meters, light signals and motions of heavenly bodies.

The relativistic critique of space and time reveals that comparison of spatial distances and periods of duration is a more complicated task than naive understanding would like to have it. What guarantees that given line segments are equal at different places, or that two given occurrences last equally long? We compare a line segment with a measuring rod, bring the rod to the other segment, make a corresponding measurement and compare the results with each other. Correspondingly, a timekeeper in an athletics competition receives, as the result of a certain runner, four minutes, adjusts his/her clock and measures another runner's performance with the same result. However, what guarantees that there were no physical changes in the rod or in the clock to the effect that the later measurements would no longer be accurate? If the equipment is tested by means of other equipment, the same question can be raised concerning the latter. We therefore lack a physical method to decide the issue, though we still rely on our measurements. Whence comes our confidence? Its source is convention, namely certain agreed systems of reference. In the case of space, such a system is either metric defined by the standard metre in Paris, or the slightly more cumbersome Anglo-Saxon system of feet, yards and miles. In the case of time, the agreed system is sidereal, which defines hours, minutes and seconds.

Reichenbach calls this conventional agreement a "co-ordinative definition", because it makes explicit a co-ordination between real rods and what is considered spatial equality, and between real clocks and equated stretches of duration. He introduces the concept in his 1924 book; cf. 1969, 8: "The physical definition takes the meaning of the concept for granted and coordinates to it a physical thing; it is a *coordinative definition*." Cf. also his (1958), section 4: "Coordinative definitions", p. 14 - 19.

Reichenbach's explication of science clarifies the difference between definitions and empirical statements. The former are based on convention, while the latter are based on facts. Reichenbach's philosophy of space and time is both relativistic and objectivistic; the objectivism is safeguarded by the posited definitions' strict admissibility conditions. Furthermore, time is logically prior to space, because spatial measurement depends on an assumption of simultaneity.

2. Cosmic Chronometry

Time is the fourth dimension of the physical world. Space has a three-dimensional structure that can be described by *x*-, *y*- and *z*- coordinates. The world-line of an occurrence is given when, e.g., a point P is indicated in this picture; then the flow of time at P is timelike world-line and other three values fix its spacelike world-line. The basic concepts for time measurement are those of unit, uniformity and simultaneity. These give the framework for the quantitative properties of time. Its qualitative properties are order and direction.

The physical order of time is characterized by the concepts 'earlier', 'later' and 'indeterminate as to time order' (Reichenbach 1958, 272). Time order is isomorphic to the points of a line. It allows for reversible processes, because "a series of points has two directions, neither of which has any distinguishing characteristic." (p. 138).

When time direction is added to time order, the process of time appears in its irreversible nature. Here the key concepts are 'past', 'present' and 'future'. The question is: "In what sense does the future differ from the past?" (Reichenbach 1991, 9). Time appears to us in an asymmetrical form that singles out the future, leaving room for anticipation, will and planned action. However, this may be only due to ignorance: it is possible that time itself is "the same in the direction of the past and in the direction of the future", which would imply that "the future is as determined as the past" (*ibid*.) Causal laws would then have a strictly nomological character. Another possibility is indeterminism, in the context of which the direction of time is interpreted as a statistical trend. Reichenbach, following the example of Boltzmann, chooses the latter interpretation of universe and considers "the evolution of the universe as a genuine probability chain" (p. 95 f).

The objections that result from deterministic physics are difficult to refute, but Reichenbach thinks that thermodynamics, microstatistics, macrostatistics, quantum mechanics yield evidence that supports indeterminism. The second law of thermodynamics, that of entropy, indicates the direction of time; it is a statistical law. Unidirectional time is doubly confirmed by quantum mechanics: in the light of it, macroprocesses are probabilistic and microprocesses have their characteristic indeterminacy.

3. Time and History

One may distinguish between physical time and time as experience. The latter has its typical inwardness, immediacy and phenomenal quality that connects it to the experience of an ego, to "my world" as it were. According to Reichenbach, "'I am' is always equivalent to 'I am now', but I am in an 'eternal now' and feel myself remaining the same in the elusive current of time." (1958, 110). Anticipation and memory blend into one overarching stream of experience. This experience is imbedded in the objective chain of physical events but, according to Reichenbach, does not give us sufficient information of those events. Rather, one may expect that a study of physical time "presents the experience of time in a new light" (p. 113). How the relation between the subjective and the objective side of time is ever understood, it is a fact that time has a special meaning for human beings; cf. the first chapter of Reichenbach's (1991): "The Emotive Significance of Time".

The question whether the asymmetry between past and future is real, has implications to human action and history. If the future is genuinely undecided, the cosmological structure of the causal net is open, and in this case "we are allowed to regard the causal net of human history, and perhaps of planetary history, as open." (Reichenbach 1991, 39). Reichenbach asks: "Do we have conclusive evidence for the openness of the net?" (p. 38) He is in fact collecting such evidence throughout his book 1991.

Indeed, one may speak of "things and persons that remain identical and unique in the flow of time" (Reichenbach 1991, 38) only if the causal structure of the universe - at least of that universe that we inhabit - is open. One may make here a stronger claim than Reichenbach's above one: there is no history in the genuine sense if closed causal chains occur, because then the unique individuality of things and persons would be lost. (Cf. also the problems of individuals and individuation treated by P. F. Strawson 1971).

In science fiction-literature, there are stories in which, as Reichenbach says, "you meet a man who claims that you are his earlier self" (1958, 141). This "would be very strange, but not logically impossible" (p. 142). The possibility of history hangs on the practical impossibility of this alternative.

As was seen above, Reichenbach distinguishes human history from planetary history. Let us give some complementary remarks. The history of our planet has behind it a huge period of cosmic history, which can be traced by calculations based on galaxies' observed red shifts. When the whole galactic system is traced back to its origin, speculation complements observation and calculation. There are various competing models of cosmic evolution, which underlines the claim that our perception of processes of duration must be distinguished from time itself - "time as an objective process", as Reichenbhach says (1991, 8). Correspondingly, the concept of history has an objective and a subjective aspect. However, time in the objective sense remains bound to processes and is nothing in itself - in so far as relativity theory is correct.

Reichenbach intended to give a dynamic picture of the physical world, as the title of his book (1991) indicates. Its first chapter contains a baffling passage that can easily be interpreted to mean that the general theory of relativity would be committed to an ahistorical conception of the universe. The context is an analysis of Pierre Laplace's deterministic interpretation of Newton's mechanics, which, if tenable, says Reichenbach, "would spell the breakdown of a realistic interpretation of time flow" (1991, 10 f). Determinism appears to be reinforced by Einstein's and Minkowski's space-time continuum. Reichenbach describes it as follows: "This timeless universe is a four-dimensional Parmenidean Being, in which nothing happens...Time flow is an illusion, Becoming is an illusion; it is the way we human beings experience time, but there is nothing in nature which corresponds to this experience." (p. 11).

This is a caricature of relativity theory, not the interpretation that Reichenbach accepts. The world that is waiting for its realization on the right side of "Time's Arrow" (cf. Arthur Eddington), is undecided. It differs from the left-side world of the past and present; and the difference is not only concerned with our knowledge. This is Reichenbhach's view, and if tenable, gives a cosmological foundation for history, understood both in the subjective and in the objective sense.

Literature

Cassirer, Ernst 2000 *Substanzbegriff und Funktionsbegriff*, Darmstadt: Wissenschaftliche Buchgesellschaft. (1910)

Cassirer, Ernst 1994 Zur Einsteinschen Relativitätstheorie. In: (Cassirer): *Zur modernen Physik*. Darmstadt: Wissenschaftliche Buchgesellschaft. (1921)

Einstein, Albert 1918 *Über die spezielle und die allgemeine Relativitätstheorie*. Braunschweig: Friedrich Vieweg & Sohn. (1916)

Gerner, Karin 1997 *Hans Reichenbach sein Leben und Wirken. Eine wissenschaftliche Biographie.* Osnabrück: Phoebe-Autorenpress, Verlag unabhängiger Autoren.

Reichenbach, Hans 1920 *Relativitätstheorie und Erkennnis a priori*. Berlin: Verlag von Julius Springer.

Reichenbach, Hans 1958 *The Philosophy of Space and Time*. Trans. Maria Reichenbach and John Freund. New York: Dover Publications, Inc. (Originally in German 1928)

Reichenbach, Hans 1965 *The Theory of Relativity and A Priori Knowledge*. Trans and ed Maria Reichenbach. Berkeley and Los Angeles: University of California Press. (Originally in German 1920)

Reichenbach, Hans 1969 *Axiomatization of the Theory of Relativity*. Trans and ed Maria Reichenbach. Berkeley and Los Angeles: University of California Press. (Originally in German 1924)

Reichenbach, Hans 1991 *The Direction of Time*. Ed Maria Reichenbach. Berkeley, Los Angeles, Oxford: University of California Press. (1956)

Schlick, Moritz 1920 *Raum und Zeit in der gegenwärtigen Physik*. Berlin: Verlag von Julius Springer. (1917)

Schlick, Moritz 1979 *Allgemeine Erkenntnislehre*. Frankfurt am Main: Suhrkamp. (1918)

Strawson, P. F. 1971 *Individuals. An Essay in Descriptive Metaphysics*. London: Methuen. (1959)

Arto Siitonen <aosiiton@mappi.helsinki.fi>