

Bruno Mölder • Valtteri Arstila • Peter Øhrstrøm
Editors

Philosophy and Psychology of Time

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Chapter 1

Introduction: Time in Philosophy and Psychology

Bruno Mölder and Valtteri Arstila

Abstract “Philosophy and Psychology of Time” comprises papers from philosophers and psychologists who work on various aspects of subjective time. In the book, the broad topic of time is examined from different aspects, divided into five parts. These main aspects are the following: the concept of time in philosophy and psychology, temporal presence, the continuity and flow of time in mind, the timing of experiences, and the relationship between time and intersubjectivity. This chapter introduces the volume and supplies a short overview of each contribution.

Time, especially the way it is experienced and the role it plays in enabling experience, has again become the focus of both philosophers and psychologists. However, it is commonplace for research in various fields to take place in isolation, without sufficient interaction between the ideas and the theoretical approaches from different disciplines. This is understandable, given the diverse objectives and methodologies of the disciplines. Notwithstanding this, the experience of time is a topic on which cross-disciplinary discussion between philosophers and psychologists would be instrumental to further progress. True, there are obstacles to such valuable interdisciplinary cooperation. But some of these obstacles are contingent, namely the use of different vocabularies and the difficulty of understanding the frameworks within which researchers of other disciplines work. Indeed, there is no straightforward translation from philosophical terms into psychological terminology and vice versa. The same applies to the theoretical frameworks which structure the debates in philosophy and psychology (which we understand broadly to encompass the study of neural processes too).

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This collection of papers aims to bridge this gap between philosophy and psychology. The book contains five parts, each dealing with a topic that is either central to the field in the sense that both philosophers and psychologists have shown a keen interest in it or is a topic that deserves, but has not yet received, more attention. These topics include the concept of time in philosophy and psychology, the notion of presence, continuity and flow of time in mind, the timing of experiences, as well as the relationship between time and intersubjectivity.

The book is structured in such a way that each topic is addressed both from the philosophical and the psychological angle, thus enabling an interdisciplinary exchange. The authors were encouraged to reflect upon the relevant concepts in their own and the neighbouring discipline and to write the chapters so that they can be understood by researchers from the other field. The chapters establish common ground in the respective field, but they also include a more detailed discussion which digs deeper into the topic and wherein original contributions to the discussion are made.

In what follows, we will provide a brief, general characterization of each large topic and the relevance of philosophy and psychology to each topic. This is then followed by more detailed accounts of the particular contributions.

The concept of time is conceived in philosophy and in psychology in various ways. In philosophy, the fundamental divide lies between the dynamic and the static conceptions and logics of time. Traditionally, one of the main issues has been which kind of vocabulary is more basic. On the side of psychology, there are also different concepts of time in play, but the central task is rather that of bringing out all those factors that influence our experience and/or judgements of time and temporal properties.

The topic of presence brings together issues in philosophy of mind, metaphysics of time and psychology of time. With respect to this topic, philosophers seek to describe the temporal phenomenology of consciousness and to establish which metaphysical account is in best accord with such phenomenology. Psychologists, however, are interested in the processes underpinning different levels of temporal moments that could be called “present.”

The main concern with regard to subjective continuity and the flow of consciousness is the putative conflict between the seemingly continuous nature of consciousness and the discrete nature of the underlying neural processing. This is definitely a topic where conceptual analysis done by philosophers could help to clarify the matter, though an informed discussion by a neuroscientist on how discrete processing in the brain can give rise to continuous consciousness would be also needed.

The timing of experiences pertains to whether the apparent temporal order of experience matches with the objective order of events that are perceived and to the order of brain processes that underlie these experiences. Answering these questions requires careful interpretation of experimental results, and in this regard empirical input from psychologists could complement the philosophical debate.

Finally, the topic of time and intersubjectivity is one that has not been sufficiently explored. At the same time, it has often been stressed that proper timing is crucial for intersubjective action. The philosopher’s role would be to clarify exactly

what role time plays in coordination between persons, whereas psychologists could build specific models of the involvement of time in intersubjectivity.

Now we turn to the characterization of particular contributions to the volume.

Part I. The Concept of Time in Philosophy and Psychology The aim of the part on the concept of time is to give a general overview of the various concepts of time in philosophy and psychology, at the same time keeping an eye on the possible connections between the respective terminologies. All contributors to this part also apply their discussion to our everyday concerns about time, exemplifying how advancements in philosophy and psychology help to make sense of the elements of our daily experience.

Part I begins with a chapter by Peter Øhrstrøm, who attributes the well-known difficulty of defining time to the fact that time is so fundamental that it cannot be defined in more basic terms. Although there is no reductive account of time to be had, we can still understand time and talk about it. Øhrstrøm introduces the basic distinction between the *dynamic* (A) and the *static* (B) languages of time and proceeds with the question of which language is the fundamental one. He gives an overview of Arthur Prior's temporal logic and argues that this framework incorporates both languages. Yet, it can also be shown that the A-language is richer and more basic than the B-language. Furthermore, Øhrstrøm illustrates the usefulness of a formal approach to time by showing how it helps to make sense of common claims about time and solves age-old puzzles such as the problem of how statements about future contingent affairs could be true at present.

Samuel Baron and Kristie Miller examine the folk concept of time. They point out that any account of this concept should accommodate the point that it is "resistant to error." This means that the concept lies in the centre of the network of our practices and experiences, which are so important to us that we are not prepared to give up the concept in light of scientific developments or philosophical arguments. Given its resistance to error, Baron and Miller argue that neither the A-series nor the B-series captures the folk concept of time. In their view, the folk concept of time is a functional one, related to our perspective on the world as agents. Time as a functional concept is multiply realizable, and this explains its resistance to error: very many things can be taken to be a realization of the folk concept.

Dan Zakay approaches the concept of time from the point of view of psychology. He distinguishes between physical time, which he terms "T", and psychological time, which he understands as a subjective feeling. Zakay points out two basic dimensions of psychological time: the succession and duration of experiences. He focuses especially on duration judgements, both in that of the retrospective and prospective variety. In retrospective judgements memory plays a role, whereas prospective judgements depend on attention. Zakay explains how shifts between prospective and retrospective timing can throw light on several experiences of time and on temporal illusions familiar from our daily life.

Part II. Presence It is common to think of the "now," temporal present, as a durationless point in time that separates the past and the future. Our awareness does not

appear to be confined to instants in time, however. First, most philosophers working on the topic argue that our experiences as of change, motion and other similarly temporally extended phenomena can be accounted for only if the phenomenal contents of our experiences are temporally extended. The idea that the subjectively experienced present moment is temporally extended is known as *the doctrine of the specious present*. Second, as psychologists have stressed, things that we are aware of result from processes that integrate stimuli (or the neural signals that relate to stimuli) over different periods of time. This applies to both “elementary” experiential features, e.g. colours and grouping, as well as to higher-level features required for intersubjective communication.

This subjective present, what we experience as occurring now, is the topic of the part II. It begins with a chapter by Sean Power, who separates different notions of present and contrasts them with the doctrine of the specious present. It is shown how the doctrine is compatible with some but not all metaphysical positions of time. Accordingly, depending on the aspect that one emphasizes—phenomenology or metaphysics—either phenomenology limits the plausible metaphysical views on time or metaphysical considerations force us to reconsider the doctrine and the phenomenology it is supposed to help us explain.

Marc Wittmann considers the topic from the perspective of a neuroscientist. He argues that one must separate three different notions of the subjective present. The shortest one, which he calls the *functional moment*, defines the simultaneity and temporal order of events—presumably this relates to other well-known temporal integration processes that occur within 100 ms too. Next there is the *experienced moment*, which segments and integrates temporal events into meaningful units. The experienced moment covers few seconds and enables an accurate and successful behaviour and inter-personal communication. The experienced moment also resembles best the notion of the specious present. Finally, by means of working memory related to the *mental presence*, functional moments and experienced moments become incorporated into a continuous, unitary mental state.

Part III. Continuity and Flow of Time in Mind Our consciousness is often described as a continuous stream of conscious experiences, as in Wittmann’s notion of mental presence. In part III, what such a view amounts to is reflected upon. The topics of interest include the stream-likeness of consciousness as separate from the continuity of experience and the extent to which consciousness has the properties of continuity and stream-likeness. The latter topic is particularly interesting because psychological results appear to be in tension with the phenomenology—the results are sometimes taken to suggest that our experiences result from discontinuous processes and that succeeding experiences do not relate to each other in any substantial manner.

Oliver Rashbrook-Cooper approaches these issues from the philosophical tradition. Taking phenomenology as his starting point, he argues that the stream of consciousness does not boil down to having experiences succeeding each other without any apparent gap. Instead, Rashbrook-Cooper argues that the stream consists of *Phenomenal Continuity* and *Phenomenal Flow*. The first of these terms refers to the idea that the temporal boundaries of experiences are not exhibited in the phenome-

nology, whereas the second term refers to the idea that consciousness appears to us as a flowing phenomenon even if what we are conscious of remains the same. As a result, the gaps in experiences (which concern the contents we are conscious of) suggested by the psychological results do not threaten the stream-likeness of consciousness.

Tamas Madl, Stan Franklin, Javier Snaider and Usef Faghihi approach the topic from the perspective of cognitive neuroscience and modelling. Their focus is on the question of how succession and duration—i.e. the temporally extended events that studies of time perception are concerned with—can be perceived in the framework of the Global Workspace Theory. This issue is particularly pressing because the Global Workspace Theory is one of the major theories of consciousness and it postulates that the mechanisms behind conscious perception are discrete. They show that time perception is indeed possible in this framework by providing a computational model of the Global Workspace Theory, where time processing relies on perceptual associative memory as well as on short-term and long-term nodes grounded on sensory feature detectors.

Part IV. The Timing of Experiences In part IV, we turn to the timing of experiences. The focus is again on the theoretical issues: what determines the (apparent) time of events? The discussion thus does not concern directly the actual time when a stimulus is experienced as measured in milliseconds—something that Visual Awareness Negativity and Late Positivity aim to address—nor does it concern factors (such as intensity, location and the modality of the stimulus) that undoubtedly modulate but do not determine the time when a stimulus is experienced. Instead, at the heart of the matter lies the relationship between (i) the apparent time of experienced events and (ii) the time of the neural processes underlying the experiences of events. Do the two necessarily match or can they come apart?

Valtteri Arstila addresses this issue in the context of philosophical debate concerning postdiction effects and more precisely in relation to apparent motion. (In postdiction effects, later occurring events influence our perception of events taking place before them.) Since this debate is intimately tied up with the larger philosophical issue of the doctrine of the specious present mentioned above, he also approaches the issue of the timing of experiences from the subjective point of view: i.e. how must the apparent temporal structure of experiences be constituted if a single unified experience can represent that two events occurred at different time? In the end, Arstila suggests that the doctrine can be rejected and that the apparent time of an experienced event matches with the time of neural processes underlying the experiences.

Kielan Yarrow and Derek Arnold, in turn, approach the timing of experiences from the perspective of psychology. They focus on how to explain the results obtained from simultaneity and temporal order judgement tasks. After considering existing explanations, they emphasize that most results can be explained by assuming that the apparent time of experienced events is the same as the time of the neural processes that realize the experiences of events. This is supported by the fact that the suggested neural mechanisms underlying our performance in these tasks follow

the same assumption. Thus although Yarrow and Arnold do not conclude that the time of neural processes determines the experienced simultaneity and succession of events, they argue that the competing views must be made more concrete before they can be considered to be real alternatives.

Part V. Time and Intersubjectivity Appropriate timing is central for successful on-line intersubjective action and, indeed, this has often been pointed out in accounts of social cognition. However, it has not been explored with sufficient depth and clarity. What role do time and the sense of time play in coordination between people? How could philosophy contribute to the study of this? What is the role of timing in human development? Does the development of intersubjective communication depend on temporal factors? These are some of the issues considered in part V.

Bruno Mölder explores the role of time in intersubjective processes from a philosophical perspective. For this, he relies on some tools from the philosophy of science. In particular, he generalizes Carl Craver's account of explanation in neuroscience to temporal and interactive processes between people, drawing a distinction between causally relevant conditions, constitutive components, temporal constraints and background conditions. With this set of tools, he then analyzes the mother-infant interaction and time-related phenomenological explanations that have been given for some psychopathological cases such as schizophrenia and depression. This allows for more varied and specific conclusions concerning the role of time in interaction between people.

Colwyn Trevarthen gives an all-encompassing overview of the role of time in our lives, delineating how innate motivation for intersubjective action forms the basis of our more sophisticated cognitive abilities, related to communication and culture. He shows how our social skills develop through various stages, starting from inborn capacities to imitate and share rhythms, and leading to shared culture and language. In such actions, temporal parameters related to rhythm and musicality are crucially important. Besides providing the synthesis of a wide range of developmental facts, Trevarthen discusses also the neuroscience of action and emotion, focussing especially on the importance of rhythmic movements.

We hope that this book will be of interest to both philosophers and psychologists. On the one hand, the chapters cover those key issues in the philosophy of time and mind that psychologists have also tackled. On the other hand, the volume provides an easily approachable exposition of psychological research on time that might be crucial for resolving philosophical debates, thereby extending the range of examples for the scrutiny of philosophers.

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Chapter 2

The Concept of Time: A Philosophical and Logical Perspective

Peter Øhrstrøm

Abstract As pointed out by St. Augustine we cannot give a proper definition of time as such. Furthermore, conceiving time as a literal object would be highly problematic. It is, however, possible to establish a conceptual framework for meaningful discussion of the temporal aspects of reality in terms of the philosophical logic of time developed by Arthur Norman Prior. This framework is based on the view that John McTaggart's A-language is more fundamental than the B-language. Prior's view can be seen as based on some important properties of human experiences of time, and it involves the claim that it is useful to study the temporal aspects of reality in terms of so-called branching time models. This can in fact be done in several ways. It turns out that some of the most attractive and richest theories based on the ideas of branching time may be seen as formalisations of medieval and other early suggestions made by scholars such as William of Ockham and Luis de Molina. The tense-logical formalism appears to be useful wherever it is important to reason strictly regarding the temporal aspects of reality. Prior's approach gives rise to a formal language which is relevant in the context of Julius T. Frazer's hierarchical understanding of time as such and in the study of time in general. It offers a very powerful way to deal with time in a conceptually consistent, systematic and precise manner.

In any discussion concerning the notion of time it is commonplace to refer to Augustine's famous comments on the difficulties we face when answering the question, "What is time?" Augustine gave an astute formulation of the problem:

What, then, is time? If no one asks me, I know what it is. If I wish to explain it to him who asks me, I do not know. (Augustine 1995, Book 11)

The problem seems to be that although time is an essential and well known aspect of reality, we nevertheless cannot properly define it. But why is it so difficult to provide such a definition?

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It may perhaps be argued that the reason is simply that although we refer to time again and again in our daily life, there is no precise reality which the term stands for. According to this view, the substantive “time” covers a number of very different and only rather loosely connected ideas; there is no single object or entity. If we followed this line of thought, it would not be possible to speak about the concept of time as something meaningful and precise, something that can be studied as a true element or aspect of reality. In consequence, ideas of time would have to be understood as nothing but social constructions.

There is clearly something to be said in favour of this view. The most common modern idea of time can to a large extent be seen as a product of cultural and technological development. As Lewis Mumford (2010, 15) points out, modern clocks helped “create the belief in an independent world of mathematically measurable sequences.” This view of time as a literal object has been questioned by Arthur Norman Prior (1914–69), who has suggested that we simply have to drop the idea:

But instants as literal objects ... going along with the picture of time as a literal object, a sort of snake which either eats its tail or doesn't, either has ends or doesn't, either is made of separate segments or isn't, and this picture I think we must drop. (Prior 1967, 189)

On the other hand, the passage of time seems to be a crucial element of our life as human beings. And how can this be so, if time does not refer to any aspect of reality at all? In this paper, it will be argued that we can in fact speak meaningfully about the temporal aspects of reality without conceiving time as a literal object. As we shall see, it is possible to establish a conceptual framework for meaningful discussion of the temporal aspects of reality, although we cannot give a proper definition of time as such. This framework can be introduced in terms of the philosophical logic of time developed by Prior.

2.1 Prior on Time and Reality

Prior's main reason for rejecting the idea of time as a literal object is that the idea is, in his opinion, based on a mistaken view of reality. Prior (1996a, 45) claimed that: “Time is not an object, but whatever is real exists and acts in time...”. According to this view, time should in fact be understood and studied on the basis of an investigation into what exists. This means that Augustine's problem should not be answered as suggested above. Although we cannot strictly-speaking define time, this does not mean that we should drop all attempts at dealing with temporal phenomena based on a careful and true analysis of reality.

Assuming that time is, after all, a meaningful concept, we have to reconsider the question: Why is it so difficult to define time? The answer may be found in reflecting on what is involved in defining time. Given that a definition of time would have to be formulated with reference to something more basic than time, the crucial problem becomes obvious. If there is nothing more fundamental in reality than time, then it follows that a proper definition of time cannot be established. However, this

does not mean that time as such cannot be studied. St. Augustine's classical dilemma should not be understood solely as a denial of the possibility of explaining what time is. The real wisdom to be found in his answer is not only that time cannot be defined in terms of anything more fundamental, but rather that although this is the case, temporal awareness is in fact a crucial part of tacit human understanding. We actually have a proper understanding of time, although in most cases this knowledge can only be expressed in a rather indirect manner.

Prior gives us one very clear example of his view of temporal reality when he writes:

I believe that what we see as a progress of events is a progress of events, a coming to pass of one thing after another, and not just a timeless tapestry with everything stuck there for good and all.... (Prior 1996b, 47–48)

In this way, Prior maintains that what we normally call “the passage of time” should be conceived as belonging to reality. What Prior rejects as a misleading idea is time as a fixed and existing structure of events, a “timeless tapestry.” In Prior's opinion, we have to reject the so-called eternalism, according to which all events (past, present, and future) are equally real. The important question in this context is this: How can something exist, if it does not exist now? Prior defends the so-called presentism (see Prior 1972) according to which something exists if and only if it exists now. If something is past and does not exist now, then it does not exist (any-more). If something is future and does not exist now, then it does not exist (yet). In this way, Prior finds that the notions of time and existence are closely related.

Another crucial aspect of temporal reality is related to what Prior calls “real freedom.” He sees this idea as closely bound to the belief in the reality of the passage of time:

This belief of mine... is bound up with a belief in real freedom. One of the big differences between the past and the future is that once something has become past, it is, as it were, out of our reach—once a thing has happened, nothing we can do can make it not to have happened. But the future is to some extent, even though it is only to a very small extent, something we can make for ourselves.... if something is the work of a free agent, then it wasn't going to be the case until that agent decided that it was. (Prior 1996b, 47–48)

The main point here is that there is a very important asymmetry between the past and the future. The past is “now-unpreventable” and “out of our reach,” whereas the future, at least to some extent, is open in the sense that it can be formed at least in part as a consequence of the decisions we are making now.

2.2 McTaggart and Prior on Temporal Discourse

Such reflections as on the temporal aspects of reality are essential when it comes to the study of time. Although we cannot give a simple and precise definition of time, we can in fact speak meaningfully about the temporal aspects of reality based on common human understanding. This can be done in several ways. Since the time of

John McTaggart (1866–1925), most discussions about time make use of his A- and B-language classifications. These classifications of time derive from McTaggart's famous paper, "The Unreality of Time" (1908), in which he introduced two fundamentally different ways of dealing with time, the A-series and the B-series (corresponding with what we call here, the A- and the B-language). This dynamic approach is formulated in terms of an A-language ("past," "present" and "future"). The approach is based on the view that there is a fundamental asymmetry between past and future, which is not only a feature of the human mind, but an essential aspect of reality. This view may be compared with a more static or structural understanding of time according to which the basic notions are "before," "after" and "simultaneous with" (the so-called B-language). The A-language will be used if time is seen from "within," whereas the B-language will be relevant if a temporal system is seen from the "outside" that is, from a God's eye perspective.

Prior argued that the A-language is much closer to human experience of time than the B-language. His most famous argument was first published in the paper "Thank Goodness That's Over" (1959). Later the argument was rephrased as:

... what we know when we know that the 1960 final examinations are over can't be just a timeless relation between dates because this isn't the thing we're pleased about when we're pleased that the examinations are over. (Prior 2003, 42)

As Prior sees it, this shows that knowledge based on temporal experience has to involve A-notions. For this reason, Prior held that the A-notions are conceptually basic, and that the B-notions are secondary.

Prior developed McTaggart's classification further, claiming that the distinction between these two languages can in fact give rise to some important philosophical positions regarding time. However, Prior also pointed out that any analysis should include the notion of temporal (or historical) necessity, that is, the notion of what is "now un-preventable." This is crucial in the account of the asymmetry between the past and the future.

In discussing which concepts should be regarded as the primary (or primitive) temporal notions regarding the understanding and description of reality, the A-notions or the B-notions, Prior argued that there are not only two possible answers to this problem. In this case Prior followed his standard procedure, according to which he first of all had to describe the positions which could in principle be held. Based on this account he would then have to explain which of the possibilities he himself would prefer, and he would have to give his reasons for this choice.

Given that the role of temporal necessity has to be taken into consideration, Prior demonstrated that we can in fact formulate four different positions, corresponding to what Prior calls "grades of tense-logical involvement":

1. The B-notions are primary regarding the understanding of the temporal aspects of reality, and the A-notions can be conceptually derived from the B-notions.
2. Ontologically, the A- and B-notions should be seen as on a par. Neither has conceptual priority over the other.

3. The A-notions are primary regarding the understanding of the temporal aspects of reality, and the B-notions can be conceptually derived from the A-notions. The basic A-language includes a notion of what is “now un-preventable.”
4. The A-notions are primary regarding the understanding of the temporal aspects of reality, and the B-notions can be conceptually derived from the A-notions. The basic A-language does not include a notion of what is “now un-preventable.” This modal notion can be conceptually reduced to the classical A-language of past, present and future.

These grades of tense-logical involvement may be introduced in terms of tense- and modal-logical formalisms. The formal language suggested by Prior was in fact an extension of proposition logic with three propositional operators, P , F and M . This means that if q is a proposition, then we can form new propositions using the operators:

Pq : “it has been that q ”

Fq : “it will be that q ”

Mq : “it is possible that q ”

Given these three basic operators, it is possible to define their dual operator in this way:

Hq : “it has always been that q ,” defined as $H \equiv \sim P \sim$

Gq : “it will always be that q ,” defined as $G \equiv \sim F \sim$

Nq : “it is necessary that q ,” defined as $N \equiv \sim M \sim$

If one wants to go beyond the third grade of tense-logical involvement and embrace the fourth grade, then M (and N) become definable in terms of P and F (with the usual machinery of propositional logic).

It should be added that in order to deal with time in terms of tense-logic, Prior also used the so-called metric tense-operators, $P(x)$ and $F(x)$, which stand for “ x time units ago it was the case that...” and “in x time units it will be the case that...”

The above formalism is A-theoretical and one of the tasks which Prior wanted to carry out was to explain how this approach relates to the B-language (static time), which is based on the assumption of a set of instants, ($TIME, <$), ordered by a before-after relation (and a simultaneity relation), and including a formalism of $T(t, p)$ (i.e. “ p is true at the time t ”). In the B-language, the tense operators can be introduced in the following way:

$$T(t, Fp) \equiv_{def} \exists t_1 : t < t_1 \wedge T(t_1, p)$$

$$T(t, Pp) \equiv_{def} \exists t_1 : t_1 < t \wedge T(t_1, p)$$

Prior himself held that the A-language is conceptually primary. This means accepting at least the third grade of tense-logical involvement. After a few years of work with the development of his tense-logic, Prior decided to defend the fourth grade.

In his many papers and books, Prior demonstrated how the B-language can be constructed fully in terms of the A-language (but not vice versa). In other words, he proved that the B-language can be formally derived from the A-language.

A major point in Prior's construction of the B-language from the A-language (grades 3 and 4) is that temporal-instants may be conceived as a special class of very rich propositions. Consider any of these instant-propositions and an arbitrary other proposition, q , then the crucial property of the instant-proposition will be that it either necessarily implies q , or that it necessarily implies the negation of q , i.e. $\sim q$. Prior has demonstrated that the system of such instant-propositions will have all the formal properties required of a B-theory based on the notion of "being true at an instant." In this way, the B-language may in fact be established in terms of the A-language. (More details can be found in Prior 2003, 117 ff. and Øhrstrøm 2011). In this way, Prior (1967, 74) is able to establish the abstract idea of time. Prior argues that "time appears as a class of classes of propositions ordered by a certain relation." The classes of propositions to which Prior refers, are in fact equivalent to instant-propositions and time is conceived as the ordered set of such instant-propositions. An instant-proposition, i_1 , is supposed to be before another instant proposition, i_2 , if and only if i_2 necessarily implies Pi_1 . In fact, it can be proved based on some rather minimal assumptions that this is the case if, and only if i_1 necessarily implies Fi_2 .

Prior carried out a number of further studies of the instant-propositions understood as a special class of very rich propositions (see Prior 2003). In doing so Prior also became the founding father of so-called hybrid logic. In general, Prior's development of temporal logic and hybrid logic has given philosophers and logicians a very powerful and precise framework for further studies of the temporal aspects of reality.

2.3 Frazer's Ideas on Time and Reality

The various kinds of temporal discourse needed in order to deal with reality have also been analysed by Julius T. Frazer (1923–2010) who describes a general system of temporal discourse in which there are several levels of complexity when dealing with time and reality (Frazer 1978, 422). Frazer's levels are paraphrased below:

1. Atemporal: a world without reference to causation or temporal order.
2. Prototemporal: a world in which the only temporal references are statistical tendencies.
3. Eotemporal: a world without now, physical matter exists, time is orientable but not time-oriented.
4. Biotemporal: a world characterised by limited temporal horizons, organic present, teleological causation.
5. Nootemporal: A world in which intentionality, past/present/future, and human freedom are all meaningful notions.
6. Sociotemporal: A society referring to temporal order and organisation.

Frazer's hierarchical theory of time can be compared with both McTaggart's approach and Prior's grades. Clearly, Frazer's levels one to three may be discussed in terms of the B-language (and this language may in a certain sense not even be needed at all at the very first level). However, in order to deal with levels four to six, the A-language will be needed as well as the B-language. If levels one to six also represent the historical order of things, it may be argued that this shows that the B-language is historically fundamental as a kind of physical time, and that the appearance of the A-language should be seen as linked to the creation of biological organisms with some kind of mental or psychological awareness. However, this is not necessarily the most attractive approach to the problem of time. At the very least, we should also discuss the topic from an epistemological point of view. This means relating everything to the notion of knowledge and the process of obtaining knowledge, and it also means that Frazer's levels should not be understood as ontological levels. Such an approach would obviously depend on a conceptual analysis of human cognition. What does it mean that I have obtained or gained new knowledge? From a temporal point of view it clearly implies being aware of something which I wasn't aware of earlier. Conceived of from this epistemological perspective, the A-language in particular should never be completely overlooked when studying time, even if the description of the subject matter at Frazer's lower levels (one to three) does not seem to call for more than a B-language. When Frazer's hierarchical system is presented in this manner, the lower levels (one to four) have to be understood from the perspective of level five (i.e. human awareness), and the same holds for the higher and even more complex level six. In this way, the order downwards in the system (levels four, three, two, one) corresponds to an increasing abstraction according to which more and more aspects of the human perception and understanding of time (level five) are ignored.

2.4 Is Time Mind-Dependent?

Assuming Prior's third and fourth grades of tense-logical involvement it seems that time depends on human cognition. If we assume that Frazer's levels roughly correspond to the historical order of events in the universe, then it seems that there was a time before the first biological awareness (levels one to three). At this time, there were no human beings. But should it be assumed that this time was now-less, since the now is only possible if there are human beings or other minds to whom temporal awareness is important? If we accept Prior's analysis of the relations between the A- and B-notions in Sect. 2.2, we have to conclude that the idea of a now-less time has to be rejected. Even before the very first human mind, it would be sensible to speak of a now. The point is that we can meaningfully refer to what a human being would have experienced, if he had been there. This reference to a counterfactual observer seems in fact to be the only way in which we can meaningfully speak of these early stages of the world's history, unless we want to refer to a non-human or even divine observer. In fact the very use of the term "history" may be taken as indicating that we have to describe the stages in question using our temporal discourse.

In his construction of the temporal-instants needed in the B-language it is clearly Prior's strategy to present past instants as conceptually derivable from the now, which in this way turns out to be extremely rich and meaningful. In fact, not only past instants, but also the instants in the open future and even the counterfactual instants can be conceptually constructed in this manner.

It should be pointed out, however, that we cannot exclude the possibility of describing the world without any reference to our temporal awareness. The point is that we as humans cannot have any direct access to a cognition of this kind. But an atemporal cognition may certainly be possible from a divine perspective. For example, St. Thomas Aquinas seems to have held that God's knowledge is in some way outside of time. Prior discusses this possibility in his paper "The Formalities of Omniscience" (Prior 2003, 39–58), and he has convincingly argued that the kind of knowledge which is interesting and relevant from a human point of view will be conceptually related to our temporal awareness conceived in terms of the A-language. This does not prevent us from discussing and studying what was the case before the creation of mankind. Nor does it exclude us from a rational discussion of what could counterfactually have happened on the Earth, had things gone otherwise than they actually did.

It should be mentioned that Prior had a strong interest in the differences between divine and human knowledge as seen in relation to the concept of time. Indeed, much of his early work on the problems of time was motivated by his wish to find acceptable answers to the classical problem regarding the logical tension between the two Christian doctrines of divine foreknowledge and human freedom. In fact, his work on this problem strongly stimulated his development of formal tense-logic. As we shall see in the next section, he argued that the use of tense-logic may lead to a deeper understanding of the temporal aspects of reality.

2.5 Treating Time in Terms of a Tense-Logic

Prior is the founding father of modern temporal logic. He invented a formal language that made it possible to treat philosophical and conceptual problems related to time in a systematic and precise manner. Arguing for the importance of this project he wrote:

And I think it important that people who care for rigorism and formalism should not leave the basic flux and flow of things in the hands of existentialists and Bergsonians and others who love darkness rather than light, but we should enter this realm of life and time, not to destroy it, but to master it with our techniques. (Undated note; kept in the Prior Collection, Bodleian Library, Oxford)

In terms of this tense-logical formalism, time may be discussed semantically. In order to do so, we also need a more precise idea of truth. For instance, we may discuss whether or not the proposition "Joe is drinking beer" is true. We may of course discuss who exactly Joe is. We may also discuss what it means to drink beer and

what beer is. For instance, should a non-alcoholic beer be accepted as a beer? But as soon as semantical questions of that kind have been answered, we may at least in principle be able to find out by a rather simple inspection of the facts which of the two basic statements (“Joe is drinking beer” and “Joe is not drinking beer”) is the true one and which of them is (right now) the false one. This seems to be based on a very basic principle, which may be seen as a version of the so-called principle of correspondence:

(C) A statement is true now if and only if the statement corresponds to facts about the present reality.

This means that the proposition “Joe is drinking beer” is true now if, and only if, it is a fact about the present reality that he is drinking beer. If that is in fact the case then it will now and at all future times be un-preventable i.e. it is and will always outside the control of Joe and everybody else that he has been drinking beer at this (present) time. Before he started to drink he may perhaps have chosen otherwise, but even when he is in fact drinking beer it seems un-preventable (i.e. outside the control of anyone) that right now he is drinking beer, although he may of course choose to stop his drinking—perhaps even very soon. Either there are facts about the present reality which makes the proposition in question true or there are no such facts. The existence of such facts may depend on what we did in the past, but it does not depend on what we are doing in the future.

Given the tense-logical formalism, Prior (1967, 74) argued that statements such as “Time will have an end,” “Time is circular,” “Time is continuous,” etc. can be treated as meaningful without assuming “that there is some monstrous object called Time, the parts of which are arranged in such-and-such ways.” The meanings which can be given to such statements arise from tense-logical formalism. This means that the statements can in fact be translated into tense-logical statements which can then be handled as any other logical problem. In Prior’s words:

Tense-logic [can be seen as] as giving the cash value of assertions about time. Postulates of the sort ... can be regarded as giving the meaning of such statements as “time is continuous,” “time is infinite both ways,” and so forth. (Prior 1967, 74)

The idea is that a theory of time should be formulated as a tense-logical system i.e. a system with some axioms and rules of inference. The properties of time can then be explored by investigating the theorems of the system; that is, the property we want to discuss is translated into a tense-logical statement and it is then investigated whether the statement can be proved in the system.

For instance, the claim that “time is dense” corresponds to the statement, $Fq \supset FFq$ (i.e. “for any q , if q will be the case, then it will be the case that it will be the case that q ”). This means that time is dense if, and only if, $Fq \supset FFq$ is a theorem in the tense-logical system we are studying. The idea behind this statement is that if something is going to happen at a later instant, t , then it will be that it will be the case, which means that there is another instant, t' , which is later than the present instant and before t . In other words, this means that for any future instant, t , there will be another instant between now and t .

Another example could be the claim that “time has a last moment” which translates into the statement, $Gq \vee FGq$ (i.e. “for any q , either it will always be that q , or it will be the case that it will always be that q ”). The point here is that if there is a last instant, t_{Final} , then Gq will be true at t_{Final} , no matter what q stands for, since at the last instant there is no future at all (i.e. it is an empty fulfilment). The idea here is that the first part of the disjunction, $Gq \vee FGq$, is true if we are already at the ending of time and that the other part of the disjunction is true if the ending of time is still to come.

2.6 The Idea of Branching Time

In September 1958 Prior received a letter from Saul Kripke. In this letter Kripke, only 17 years at the time, mentioned some errors in Prior’s book *Time and Modality* (1957) and also suggested the use of what we now call branching time (see Ploug and Øhrstrøm 2012). Prior accepted Kripke’s idea and over the following decade he developed it further in several ways. In fact he considered at least two main kinds of branching time systems. First, he considered the so-called Ockham system, which is shown in Fig. 2.1.

The idea in this kind of graphical representation is to focus on the branching moments or instants at which there is a choice between two or more alternatives. This kind of illustration may be useful but, as Prior pointed out, they are in fact no more “than handy diagrams; they need not be taken with any great metaphysical seriousness” (Prior 1967, 74).

The diagram below is named after the medieval logician William of Ockham (c. 1287–1347) who studied the logical tension between the two Christian doctrines of divine foreknowledge and human freedom. It was important for Ockham to maintain that God has complete and perfect knowledge regarding the contingent future.

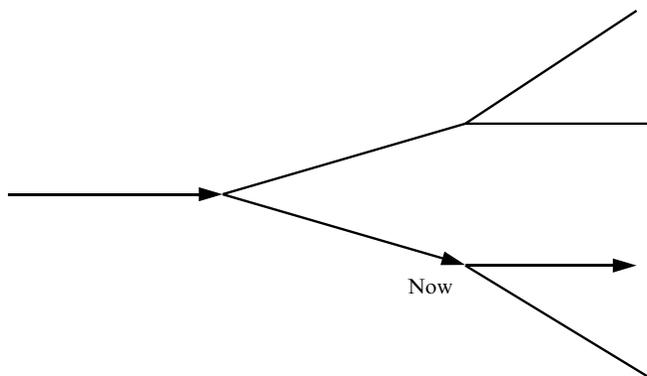


Fig. 2.1 The Ockhamistic view of branching time according to which there is a chronicle now representing the true future

In the above diagram this is indicated by the arrows which represent the course of events known in advance by God. In an unpublished paper circulated in 1965 or earlier, Prior explained this idea, claiming that in the Ockhamistic system “there is a single designated line (taking one only of the possible forward routes at each fork), which might be picked out in red, representing the actual course of events” (*Postulate Sets for Tense Logic*, Bodleian Library, Oxford). This means that according to Ockham not all future possibilities have the same status. One of the possible future courses of events is privileged in the sense that it is the true one, that is, the course of events already known to God.

In his conceptual and logical analysis Prior accepted that the Ockhamistic solution is a consistent theory which should be taken into account. However, he found some consequences of the theory rather problematic. A major problem for him was that the theory means that we can by our present and future acts influence what God knew earlier. In this way, the theory seems to violate a crucial and fundamental aspect of reality, namely that the past is fixed and nothing we can do now can change the past. Indeed William of Ockham (1969) himself was aware of this problem. His response was that as humans we obviously cannot know exactly how divine omniscience works. In addition, he made a distinction between what is properly past and what is only apparently past. When I make a decision regarding tomorrow, I may influence the truth-value of a prophecy stated yesterday about what was going to happen in 2 days. However, a statement on what was yesterday going to happen 2 days later is not a statement about yesterday (but actually rather a statement about tomorrow). Such a statement is only apparently about the past. It is not about the proper past.

Another problem related to the Ockhamistic model is that if God knows what is going to happen in the contingent future and makes His knowledge known to the persons involved, then what is said becomes necessary given that God cannot be mistaken. However, Ockham himself had an answer to this problem. According to Ockham, God does not normally communicate unconditional prophecies to the persons involved. Ockham gives an example from the Old Testament referring to the prophet, Jonah, who was asked to go to Nineveh, where he should proclaim: “Forty more days, and Nineveh will be overturned” (Jonah 3.4). However, as we learn from the Bible, the citizens of Nineveh repented and the city was not overthrown at that time. But does this mean that the prophecy was in fact false when it was stated? According to Ockham, we should understand the prophecy of Jonah as presupposing the condition “unless the citizens of Nineveh repent.” Obviously, this is in fact exactly how the citizens of Nineveh understood the statement of Jonah! Viewed as conditional, the prophecy may still be true. Ockham’s point seems to be that although God knows the truth-values of the unconditional prophecies regarding the contingent future, He does not communicate this knowledge to human beings. In this way God’s unconditional knowledge concerning the contingent future remains silent. Still, it is conceptually important that God knows the truth-value of any future contingency.

2.7 Prior's Rejection of the Ockhamistic View of Time

Prior studied the logic of the classical Ockhamistic view carefully, and he suggested a formalisation of this medieval solution. Although Prior in the end did not support this solution, his work with the model became very important, since it turns out that some other important models (including the one he himself defended) can be formally defined in terms of the Ockhamistic model.

Prior found the Ockhamistic rebuttal of determinism attractive, but in his opinion it was also rather problematic to assume that a future contingent could be true now. If a statement regarding the future is in fact true now, then there must be a strong evidence for it according to Prior. And when it comes to the contingent future, we have no such evidence. As a result Prior found it problematic to assume that one future possibility has priority over another as to which is going to be real. Although he argued that the Ockhamistic model is formally consistent, he did not find its conceptualisation of the idea of an open future acceptable. He maintained that all alternative futures should be given the same conceptual status as possibilities. Instead, he suggested and defended the so-called Peircean system. His view can be illustrated in terms of the branching time diagram shown in Fig. 2.2.

Prior argued that if a statement about the future is in fact true now, then there must be some strong evidence to support it which would also mean that the statement is now unpreventable. In terms of the problem of divine foreknowledge and human freedom he held that what God knew yesterday (or at any other past time) regarding the future, must (necessarily) be the case. Even in this sense we wanted to maintain the principle of the fixed past. In order to avoid determinism and maintain a belief in the reality of human freedom, he then found that he had to reject the doctrine of complete divine foreknowledge regarding the contingent future. Consider once more the person Joe who is free to decide to drink (or not to drink) beer tomorrow at noon. According to the Priorean view it cannot be true now

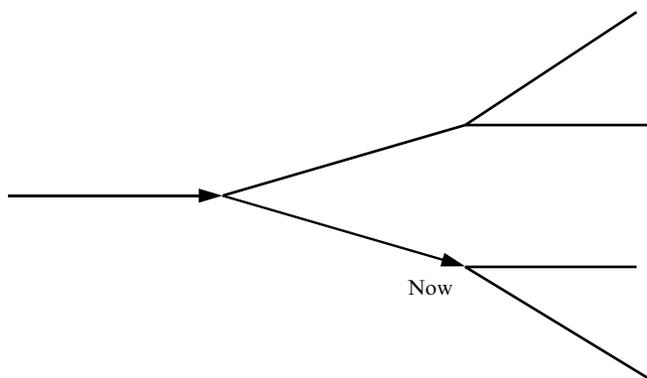


Fig. 2.2 The Priorean view of branching time according to which there is no chronicle now representing the true future. All future alternatives have the same status. Prior called this solution “The Peircean system”

neither that he is drinking beer tomorrow at noon nor that he is not drinking beer tomorrow at noon. If p is taken to stand for the proposition, “Joe is drinking beer,” then the two statements regarding Joe tomorrow at noon may be formalized as $F(1)p$ and $F(1)\sim p$. According to Prior’s view, both statements are false. The idea here is that since there is nothing which can make the statements true now, they must be false now. The assumption involved here are (1) that all statements are either true or false now, and (2) that a statement is only true now if there is something now which can make it true.

Prior points out, however, that it is in fact possible in a certain sense to maintain the doctrine of divine foreknowledge in a weaker sense according to which it is simply claimed that God knows everything which is true now. Since there is no truth now about Joe’s relation to beer tomorrow at noon, this limited doctrine does not imply that God knows any truth concerning Joe’s drinking or not drinking beer tomorrow at noon. It is interesting that Prior’s view in this way has given rise to a new theological position which has been termed “open theism.” This position has recently been discussed by David Jakobsen (2013).

While $F(1)p$ and $F(1)\sim p$ are both false in the Priorean system, the proposition $\sim F(1)p$ is obviously true in the system. This means that according to this view we should make a clear distinction between the following two propositions:

$F(1)\sim p$: “It will be the case tomorrow at noon that it is not the case that Joe is drinking beer.”

$\sim F(1)p$: “It is not the case that it will be the case tomorrow at noon that Joe is drinking beer.”

This distinction may of course be seen as difficult to handle at least within the scope of natural language. Most language users, based on common sense reasoning, would probably think that if it is not the case that Joe will be drinking beer tomorrow at noon, then it will be the case tomorrow at noon that he is not drinking beer. The distinction between $\sim F(1)p$ and $F(1)\sim p$ certainly appears to be a very high price to pay in order avoid determinism along with an acceptance of the principle of the fixed past.

2.8 Belnap’s Open Future

Like Prior, Nuel Belnap et al. (2001) have criticised the classical view rejecting the idea that a proposition about the contingent future can be true now. However, they do not accept the strange Priorean distinction between $\sim F(1)p$ and $F(1)\sim p$. They have argued that it is in fact possible to maintain the validity of

$$F(1)p \vee F(1)\sim p$$

without accepting the idea of a true contingent future. This can be done by rejecting the very concept of the absolute truth-value of a proposition at a moment of time.

The idea here is that the truth-value of a proposition should depend not only on the temporal moment but also on the choice of route (or chronicle) through the branching time system. This idea had in fact been developed by Prior who termed it “Ockhamistic” (see Øhrstrøm and Hasle 1995, 203 ff.), although William of Ockham certainly would have accepted what we have called the classical view.

By making truth relative to the routes (chronicles) through the branching time system, the idea of divine foreknowledge can in principle be excluded from the theory. The various possible futures then have the same ontological status. None of them represents “the future,” but they are all possible futures.

The theory suggested by Belnap et al. (2001) is elegant, and it has many followers in modern temporal logic. However, it is again a rather high price to pay in order to avoid determinism without accepting the classical view. The price in this case is that we have to drop the classical and absolute idea of truth and replace it with a more relative notion. If this worldview is accepted, the notion of truth will be rather limited. All knowledge will be conditional; i.e. truth will in principle only make sense relative to an assumed course of events. In this case there would not be any absolute truth about the contingent future which could or could not be known by anyone, and belief or a guess regarding the contingent future could neither be right nor wrong.

In terms of the example used above, this means that the statement, “Joe is going to drink beer tomorrow at noon,” does not have a truth-value right now. According to the theory the same holds for the proposition, “Joe is not going to drink beer tomorrow at noon.” According to Belnap et al. (2001) such propositions can only be true (or false) relative to the future course of events. It is like saying that if Joe is going to drink beer tomorrow at noon, then he is going to drink beer tomorrow at noon. This is certainly not surprising! But the loss of absolute truth is in fact a great loss. Very often we want to refer to the truth-value of contingent statements. For instance, we may be betting. Some say that tomorrow at noon Joe will be drinking beer; some may hold the opposite view. Some of the persons involved in this must be right (the winners), whereas others are wrong (the losers). We don’t know now who is who, but we may of course know later.

2.9 The Idea of “The Thin Red Line” in the Theory of Time

What is so wrong about the classical view defended by William of Ockham and many other great logicians? According to Belnap et al. (2001) a model such as the one shown in Fig. 2.1 does not pay due regard to the idea of alternative possibility. After all, the notion of alternative possibilities is essential when it comes to a proper understanding of the idea of human freedom. Belnap et al. have argued that if the counterfactual possibility had been chosen, one of the possible futures at any counterfactual instant would have corresponded to what would have been the true future at that instant. This means that the model in Fig. 2.1 is far too simplistic. In order to represent the notion of the true future correctly, there should according to Belnap et al. be a “selected” future route at any choice point in the diagram.

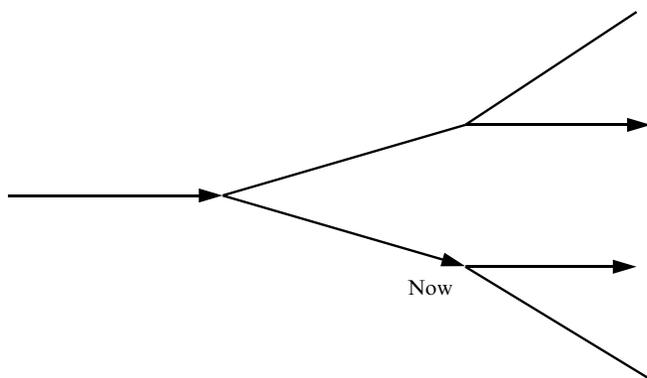


Fig. 2.3 A Molinistic model taking divine middle knowledge into account. There is a “true future” at any choice point in the diagram—even at a counterfactual instant

I believe that Belnap et al. are right and their criticism should certainly be taken into account. However their observation is definitely not new. This point was in fact well understood and defended by Luis de Molina (1535–1600), who argued that God has so-called middle knowledge. This means that God knows what any human being would freely do in any possible situation. In terms of a branching time diagram this may be illustrated in the way depicted in Fig. 2.3.

Molina pointed out that this idea of divine middle knowledge can be illustrated by an example from the New Testament:

Woe to you, Korazin! Woe to you, Bethsaida! If the miracles that were performed in you had been performed in Tyre and Sidon, they would have repented long ago in sackcloth and ashes. (Matthew 11.23)

If we take the meaning to be that in the counterfactual situation in question the people in Tyre and Sidon would freely have repented, then this would constitute an example of divine middle knowledge. According to Molina one may in this way truly speak of the free choice of human beings even in a counterfactual situation:

God knows that there would have been repentance in sackcloth and ashes among the Tyronians and Sidonians on the hypothesis that the wonders that were worked in Chorozain [Korazin] and Bethsaida should have been worked in Tyre and Sidon ... But because the hypothesis on which it was going to occur was not in fact actualized, this repentance never did and never will exist in reality—and yet it was a future contingent dependent on the free choice of human beings. (de Molina 1988, 116–117)

The analysis of the logical possibilities when confronting the doctrines of divine foreknowledge and human freedom shows that it is logically possible to uphold both doctrines in a consistent manner. A problem remains, namely the logical tension between the assumption regarding the true future (corresponding to the doctrine of divine foreknowledge) and the principle of the fixed past. The logical analysis shows that there are two options:

1. One can weaken the doctrine of divine foreknowledge. This can be done in Prior’s way (leading to “open theism”), or in Belnap’s more radical manner

according to which any truth is relative to a course of events. In both cases the price will be very high in the sense that essential parts of everyday reasoning have to be abandoned.

2. One can accept the classical idea of divine foreknowledge and drop the principle of the fixed past when it comes to God's past foreknowledge. The price is that an even higher degree of divine knowledge has to be accepted, namely that of so-called middle knowledge. In addition, we have to accept that what God knows now can be influenced by our future decisions.

It should be emphasised that although much of this discussion on time was originally formulated in a theological language, it can also be formulated in a secular language. The problem can be stated in terms of truth-values without any reference to divine knowledge. On the other hand, if we accept the so-called principle of correspondence discussed here and formulated as (C), then any discussion of truth must give rise to a discussion regarding the facts and the very nature of the present reality. It seems obvious that (1) above can be accepted without involving very much metaphysics—probably even on the basis of a purely materialistic worldview. The other possibility above, (2), seems, however, to call for an assumption regarding a deeply metaphysical nature of reality although it does not necessarily imply the classical doctrine of divine foreknowledge.

2.10 Is Time Connected?

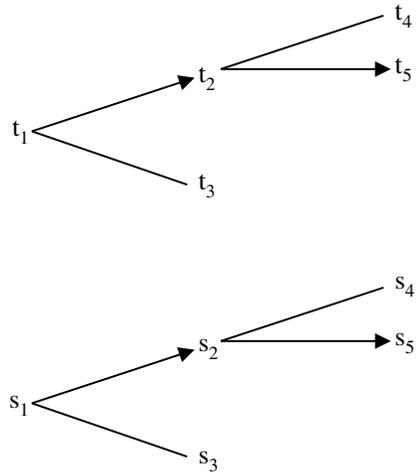
In terms of the discussion regarding the A- and B-language as well as Prior's grades of tense-logical involvement the idea of branching may be interpreted as corresponding to the third or fourth grade if the model is assumed to include an indication of the now. But can we be certain that time is connected? Is it sufficient to represent time as just one branching time system, one tree? Why not, for instance, two unconnected trees corresponding to Fig. 2.4?

The question to consider here is whether there are possible temporal-instants which cannot be accessed from our now, instants which have never been part of a possible future. But what does it mean that an instant is possible? The answer depends on whether one defends the third or the fourth grade of tense-logical involvement. Being a defender of the fourth grade, Prior wrote:

... the question as to whether there are or could be unconnected time-series is a senseless one.... but these diagrams cannot represent time, as they cannot be translated into the basic non-figurative temporal language. (Prior 1967, 199)

Prior is right given the fourth grade: on this basis, there is no way to state the possibility of unconnected instants, since possibility is defined in terms of the tense-operators (*P* and *F*). However, according to the third grade, unconnected instants would in principle be possible. Clearly, the possibility that such unconnected instants should be taken into account as a part of our world-view is highly metaphysical. On the other hand, a defender of the third grade might point out that since

Fig. 2.4 The idea of an unconnected time according to which more than one branching time system is needed in order to represent time properly



there is no strong argument against the use of an independent notion of possibility, such a notion should not be ruled out in principle. In addition, it should also be pointed out that the Ockhamistic and Molinistic versions of branching time cannot be formulated without a primitive notion of possibility. In consequence, these theories will be ruled out if we accept a world-view according to the fourth grade.

2.11 Conclusion

It has been argued that Prior’s tense-logic provides a nice and useful framework for further discussions and studies of the temporal aspects of reality. This approach to time is based on the view that McTaggart’s A-language is more fundamental than the B-language. It can be argued that this view can be seen as based on some important properties of human experiences of time. This does not mean that time is mind-dependent, but just that tenses are essential for a deeper understanding of the temporal aspects of reality. In fact, tense-logic seems to give rise to a formal language which is relevant in the context of Frazer’s hierarchical understanding of time as such. Although some of the levels in Frazer’s system do not seem to call for more than a B-language, the A-language is certainly needed at other levels.

As we have seen, it is possible to formulate a very interesting approach to the study of time based on Prior’s logical ideas. Given his tense-logical systems it is in fact possible to give meaning to basic assertions about time, such as “time is dense,” “time is not circular,” “time is branching,” “time is connected” etc. It turns out to be possible to deal with these questions in a very precise manner in terms of tense-logical formalism.

In particular, it is interesting to study the ideas of branching time. This can in fact be done in several ways. It turns out that some of the most attractive and richest

theories based on the ideas of branching time may be seen as formalisations of medieval and other early suggestions made by scholars such as William of Ockham and Luis de Molina.

In the late 1970s Prior's temporal logic caught the interest of some influential computer scientists. The most important paper on the use of temporal logic in computer science from this early period was "The Temporal Logic of Programs" (1977) written by Amir Pnueli (1941–2009). Temporal logic has since become very important in computer science and in 1996 Pnueli received the Turing Award for "seminal work introducing temporal logic into computing science and for outstanding contributions to program and systems verification" (see <http://amturing.acm.org>). It is in fact remarkable that a theory which was originally formulated in order to deal with important challenges regarding time in theology and philosophy has found its way into the field of computer science.

Given the use of tense-logical formalism, it turns out that we can create a conceptual framework that can be applied in several (if not all) sciences and at all the levels suggested by Frazer. The formalism appears to be useful and relevant wherever it is important to reason strictly regarding the temporal aspects of reality. Although this approach does not offer a complete definition of time, it does suggest a way to deal with important aspects of temporal reality in a systematic and conceptually consistent manner. This certainly makes the tense-logical approach to time very attractive.

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