Logic and Philosophy of Time

Themes from Prior, volume 1

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Edited by:
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Logic and Philosophy of Time, Volume 1

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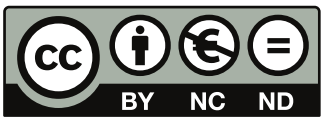

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Preface

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On 1 October 2016, the research project *The Primacy of Tense – Prior's Now and Then*[1] was initiated thanks to a grant from the Danish Council for Independent Research. The project runs from October 2016 till October 2019 and joins together research groups from six Danish universities: Aalborg University, Roskilde University, Copenhagen University, Aarhus University, Southern Danish University, and the Technical University of Denmark. The project is being led from Aalborg University with professor Peter Øhrstrøm as project leader (PI).

As the title indicates, the work of Arthur Norman Prior looms large in this project, but it would be wrong to see this as a person-centered project, even if indeed one of its goals is the further historical and systematic investigation into Prior's work. The fact that the perspective is broader and quite general will be immediately clear when one looks at the sum of themes and motivations available in the project description. Yet it also may be worth noting without any hesitation that the interest in Prior and his work has surged most remarkably over the last decades – a "rediscovery" beginning in the 90'ies and increasing almost dramatically within the present decade (even though there were important forerunners in the 80'ies)[2]. A symbolic milestone in this development was

[1] http://www.prior.aau.dk/

[2] Particularly important milestones in the late 80'ies were:

a) Peter Øhrstrøm's Higher Doctoral Thesis in 1988 (*The Concept of Time in the Exact Sciences – with Special Reference to its Rôle in Logic* (as translated from Danish) [3], and

the inclusion of an entire chapter on 'A. N. Prior's Logic' in the *Handbook of Philosophical Logic* in 2006,[3] placing him alongside logicians such as Boole, Frege, and Russell. Also the entry in *Stanford Encyclopedia of Philosophy*[4] should be mentioned here. Likewise, the number of publications dealing somehow or other with Prior's work has proliferated most remarkably – a fact to which this very volume also contributes.

A thorough exposition of the project, its themes, motivations, and methods must be found at the project site,[5] the associated WWW-site for Prior Studies,[6] in the project abstract (which is rendered on the project site), and in the full project application. However it will be useful, also as a perspective for the reading of the contributed papers, briefly to mention what one might call the matrix of the project. In the project abstract (as found on the project site), three major thematical approaches are outlined:

I. The study of Prior's Nachlass and the development of Prior studies
II. The significance of A.N. Prior's ideas in contemporary thought
III. The influence of Prior's work on logic itself and especially modern Hybrid Logic

Moreover, five systematic subject fields, or themes, are delineated:

A. The concept of time
B. Hybrid logic
C. Temporal logic and metaphysics
D. Time, determinism, and existence

b) the *Arthur Prior Memorial Conference at the University of Canterbury* (NZ) in 1989.

This conference led to the volume: Copeland, B.J. (ed.). (1997) *Logic and reality. Essays on the Legacy of Arthur Prior*. Oxford: Clarendon Press [1]. The higher doctoral thesis also was the impetus for another milestone: Øhrstrøm, P. & Hasle, P. (1995). *Temporal Logic – from Ancient Ideas to Artificial Intelligence*. Studies in Linguistics and Philosophy **57**, Dordrecht: Kluwer Academic Publishers [4]

[3]Øhrstrøm, Peter & Hasle, Per: 2006, 'A.N. Prior's Logic'. In Gabbay, D.J. & Woods, J. (editors): *Logic and the Modalities in the Twentieth Century. The Handbook of the History of Logic*. Vol. 7, pp. 399–446. Elsevier [5].

[4]Copeland, B. Jack, "Arthur Prior", *The Stanford Encyclopedia of Philosophy* (Summer 2017 Edition), Edward N. Zalta (ed.), https://plato.stanford.edu/archives/sum2017/entries/prior/ [2].

[5]See footnote 1.

[6]http://www.priorstudies.org/

E. Ethics and deontic logic

And the manner, or spirit, in which these approaches and themes are brought together is suggested succinctly by the following observation:

> By blending historical research with current research on Prior's work, we hope to demonstrate the importance of what Prior did, and to gain a deeper understanding of time in general and of the internal/external distinction in particular. We will map Prior's work ... looking for places where he endeavours to explain just what he takes the difference to be, and will explore, extend and integrate a range of technical tools, developed since Prior's death, which critically articulate his internal or tensed view of time, and extend it in directions not considered by Prior. [quoted from the project site]

The present volume is the first one in a series to be produced in the course of the project. It is to a great extent, but not exclusively, based on two project conferences this year. The first conference took part in Skagen 30 May till 01 June 2017, and the second one in Copenhagen 22 till 24 November 2017. Both conferences joined participants from the project partners as well as a number of conference contributors including distinguished invited keynote speakers from many countries, thus making these conferences genuine international events.

Acknowledgement

We are grateful for the support of Dr. Martin Prior for his support for the Primacy of Tense project. His continuing contribution to our knowledge about and understading of the work of his father A.N. Prior is and has been highly important.

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[1] Copeland, B.J. (ed.) (1997) *Logic and reality. Essays on the Legacy of Arthur Prior*. Oxford: Clarendon Press.

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In Celebration of Past, Present and Future

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Abstract

A.N. Prior's *Past, Present and Future* [18] was published 50 years ago in 1967 and was clearly a milestone in the development of tense-logic. It is a mature and comprehensive presentation of the basic concepts, systems and issues in tense-logic. In addition it also contains a number of interesting ideas that later led to important further developments of the field. *Past, Present and Future* represents a culmination of Prior's struggle with the problem of determinism (including his study of the tension between the doctrines of divine foreknowledge and human freedom). Prior's study of the problem of determinism led him to a reconstruction of the famous Diodorean Master Argument which had for centuries been regarded as a strong argument in favour of determinism. In his further analysis of the problem, he made extensive use of tense-logic and the idea of branching time. However, in *Past, Present and Future* Prior also stresses that time as such should not simply be understood in terms of branching time diagrams. Such diagrams should be seen not as direct representations of time but rather as figures helpful for understanding a deeper tense-logical structure.

Keywords: *Past, Present and Future*, tense-logic, determinism, branching time, the tensed view of time

1 Introduction

In the early 1950s, A.N. Prior (1914–1969) introduced temporal operators into logic and began work on laying out corresponding logical systems.[1] He thus became the founding father of modern tense-logic. He authored a number of publications in the field from 1953 to 1969. His first book on the topic was *Time and Modality* (1957 [16]), which was based on the John Locke lectures he delivered in 1956 at Oxford. However, his most mature presentation of tense-logic was clearly the book *Past, Present and Future* (*PPF*), published in 1967. This book represents a milestone in the development of tense-logic. The first draft was prepared during the period September 1965 to January 1966 when Prior was Flint Professor at UCLA in California (see letter from Henrik von Wright to Prior dated 17 June 1965).[2] In his lectures during this period, Prior decided to focus on the status of tense-logic. He apparently wanted to sum up and discuss the state of the art. In fact, he could not have anticipated a better climate for doing so. The logicians he met during his stay in California certainly influenced the writing of the book, as Prior himself states in its preface:

> A more recent debt is to the university of California in Los Angeles for the opportunity to lecture on these topics there, and to the very lively tense-logicians of California for many discussions with them about their results and mine.
>
> (Prior 1967, [18, p. vi])

Among those present were Nino Cocchiarella, Dana Scott and E.J. Lemmon, all from California and all logicians whose work was important for *PPF*. Their presence, as well as that of students such as Hans Kamp, Patricia Kribs, John Clifford and Richard Harschman, led Prior to praise California as the "most logically mature place in the world" (Prior 1967, [18, p. vi]). The importance of the UCLA environment for *PPF* has been noted by Copeland: "For the first time Prior found himself among a group of enthusiasts for tense logic" (Copeland 1996 [2, p. 24]). *PPF* is, as such, a summary of a decade of work on tense-logic, the product of an invigorating fellowship sparked by this invention, and points

[1] This paper is based on research in the project "The Primacy of Tense: A.N. Prior Now and Then", funded 2016–2019 by the Danish Council for Independent Research – Humanities. DFF-FKK Grant-ID: DFF – 6107–00087.

[2] All letters referred to in this paper can be found here: http://nachlass.prior.aau.dk.

forward to the subsequent publications on tense-logic that followed. It thus stands as, what Copeland rightly describes, "the most important reference in the field" (Copeland 1996, [2, p. 25]) and Woosuk Park as "one of the landmarks in the history of tense logic" (Park 2016, [13, p. 3701]). Moreover, Prior's stay in California as well as *PPF* itself influenced the revolutionary development of the project of formal semantics for natural language spearheaded by Richard Montague and consorts. Thus in *Formal Philosophy* (Montague 1974 [12]), the book collecting Montague's most important contributions to this project, Prior's tense operators are applied.[3]

Prior mailed an early manuscript of *PPF* to Nicholas Rescher, who was asked to pass it on to Georg Henrik von Wright and Richard Gale (Letter from Rescher to Prior, 23 Feb., 1966). On 21 March 1966, von Wright wrote to Prior:

> What I have seen of your work, however, makes it clear that it is important both as a major original contribution to the subject and as a very useful survey of all the work that has been done. It must be very satisfying to you to know that you started this new and exciting branch of logical study. It is still only in its beginnings and I am sure it will have a *great* future.

In the present paper, we discuss some of the major topics in *PPF*. We focus on Prior's ideas regarding the problem of determinism (Section 2), his study of the Diodorean Master Argument (Section 3), the use of the notions of branching time in the further analysis of the ideas of determinism and indeterminism (Section 4) and the tensed view of time (Section 5). Finally, in Section 6, we argue that *PPF* also includes suggestions and perspectives that later led to important further developments and discussions within tense-logic and related fields.

[3] It should be added, however, that Prior himself never became part of this movement. For one thing, he had reservations about using set-theoretical semantics for the formal language of intensional logic; for another thing, Prior's view on the relation between logic and language was more 'open-ended' and in any case, though Prior's work took much inspiration from insights into natural language, it was not a project aimed at linguistic description.

2 Determinism

Prior's focus in *PPF* is closely related to his earlier considerations on issues relating to determinism and predestination. Indeed his entire work on the logic of time, as recalled by his good friend George Hughes, "had its roots for him in classical 'pure' philosophical problems about such matters as future contingents and freewill and determinism." (Hughes 1971, [6, p. 242]). Prior's work on these problems had already begun in theological studies in the 1930s and were one of the inspirational sources which later led Prior to the development of tense-logic (see Hasle 2012 [5]).

Prior grew up in New Zealand in a Methodist home, and theology was an important part of his upbringing. However, he changed denomination to Presbyterianism in 1932 as he began his studies at Otago University. It was a fascination with Calvinism, especially the systematic character of Karl Barth's theology, which motivated the move. As a Calvinist in the 1930s and 1940s, Prior was in line with deterministic theologians like Jonathan Edwards (Prior 2014a [24]). However, it is also evident even from his early papers (Prior 2014b–c [25, 26]) that he was troubled by the implications of determinism and predestination. In time, he came to argue that a rigorous understanding of the doctrine of divine foreknowledge cannot be accepted along with the doctrine that human beings can, in some cases, choose freely between alternative possibilities. In his paper *The Good Life* (Prior 1958 [19]), Prior concluded: "Edwards's moral was 'So much the worse for freewill', mine 'So much the worse for omniscience', but the argument's the same for both of us" (1958, [19, p. 4]). Already on these grounds, Prior in the course of time had to abandon Calvinism. The argument was worked out in terms of his tense-logical formalism in *Formalities of Omniscience* (Prior 1962 [20]) and was elaborated and integrated in the broader context of *PPF*.

3 The Master Argument

Very early in his work on tense-logic, Prior studied the Diodorean Master Argument (Prior 1955 [15]), in which we find the concepts of time and determinism systematically interwoven. According to the argument, we have to reject at least one of the following propositions:

1. Every true proposition concerning the past is necessary.

2. The impossible does not follow from the possible.
3. Something that neither is nor will be is possible.

The relevance of this trilemma for determinism is obvious. If we accept 1. and 2., then we will be forced to reject that there are alternative possibilities of what will be true in the future.

Prior had worked with Diodorean ideas since the early 1950s. In this connection Benson Mates' *Stoic Logic* (1953 [10]) became very important. In a letter to Mates, Prior wrote: "I've enjoyed & profited by your book immensely" (6 August 1954). As the details, or steps, of Diodorus' original argument are unknown, Prior had to reconstruct what might have been the argument. He formulated his reconstruction in terms of tense-logic as an extension of propositional logic. In tense-logic, propositions about the future and the past are treated as operators that form propositions out of other propositions. The future F, for "it will be that", forms for instance the proposition: "It will be that there is a sea battle" from the present tense proposition "there is a sea battle". The past operator P stands for "it was the case that". Furthermore, he used the operator H (read: "it has always been that"), which can be defined as $\sim P\sim$. Finally, he used the modal operators of possibility and necessity, which in the following will be represented as $\Diamond$ and its dual, $\Box$, defined as $\sim\Diamond\sim$.

In terms of tense-logic, the Diodorean trilemma can be formulated in the following manner:

(D1) $Pp \supset \Box Pp$
(D2) $\Box(p \supset q) \supset (\sim\Diamond q \supset \sim\Diamond p)$
(D3) $\sim p_0 \wedge \sim Fp_0 \wedge \Diamond p_0$, for some proposition p_0

However, in order to demonstrate that the combination of (D1–3) leads to a contradiction, Prior needed the following two additional assumptions:

(D4) $\Box(p \supset HFp)$
(D5) $(\sim p \wedge \sim Fp) \supset P\sim Fp$

According to Prior, (D4–5) are "likely to have been taken for granted by Diodorus and by his main opponents" (Prior 1955, p. 211).

(D1–D5) lead to a contradiction in the following way:

(1) $\sim p_0 \wedge \sim F p_0$ (from D3)
(2) $\Diamond p_0$ (from D3)
(3) $P\sim F p_0$ (from 1 and D5)
(4) $\Box P\sim F p_0$ (from 3 and D1)
(5) $\sim\Diamond\sim P\sim F p_0$ (from 4 and def. of $\Box$)
(6) $\Box(p_0 \supset \sim P\sim F p_0) \supset (\sim\Diamond\sim P\sim F p_0 \supset \sim\Diamond p_0)$ (from D2)
(7) $\sim\Diamond p_0$ (from D4, 5, and 6)

The combination of (2) and (7) is obviously a contradiction.[4] Diodorus' own contention was that we have to abandon (D3), and this leads to the fatalistic conclusion that every possible event is bound to happen now or in the future. Prior accepted the validity of the argument, that is, that we cannot consistently hold all of (D1)-(D5) and hence have to give up on at least one of them. However Prior wanted to maintain (D3), holding that some possibilities will never come to fruition. In the later chapters of *PPF*, he explored two alternate ways of avoiding the contradiction. As we shall see, his Ockhamistic solution is based on the rejection of (D1) whereas his so-called Peircean solution is based on the rejection of (D4).

In *PPF*, the reconstruction of the Master Argument stands as a powerful demonstration of the usefulness of tense-logic. It also exhibits one of the hallmarks of Prior's work and thought, in which historical and systematic studies are closely interwoven – indeed to the point where sometimes the distinction almost seems obliterated. We find in this approach of Prior's an interaction between historical and systematic studies which is rare, but also sets an example. From the study of Diodorus, inspiration for the development of tense-logic would flow; and from the use of logic, new and improved understanding of Diodorus would flow. The same can be said about this manner of studying other Ancient and Medieval logicians throughout Prior's work.

4 Branching Time

Prior's original analysis of the Master Argument and Diodorean modality was based on a linear conception of time. The argument and its analysis were also mentioned in *Time and Modality* (Prior 1957 [16]).

[4] See Chapter 3 (p. 32 ff.) of *PPF*.

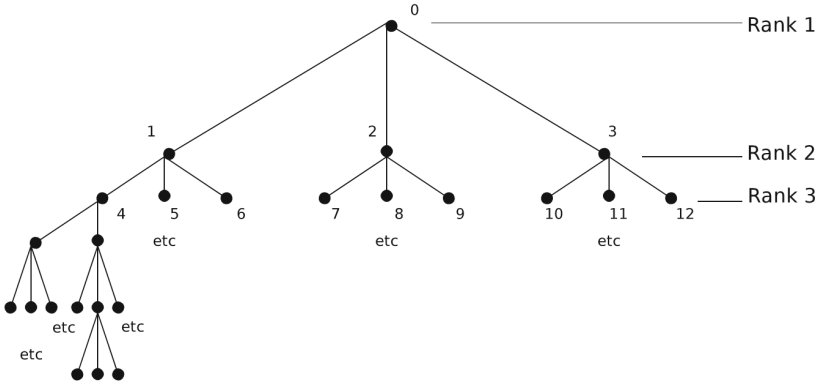

Figure 1: Saul Kripke's diagrammatical presentation of branching time in a letter to A.N. Prior dated 3 Sept. 1958.

However, the linear conception was challenged in an early and important response to the publication of *Time and Modality*, namely by the 17-year-old Saul Kripke (Ploug & Øhrstrøm 2012 [14]). In his letter dated 3 September 1958, Kripke suggested a new model for representing time in relation to Prior's discussion of indeterminism. Kripke's diagram does not represent time as linear, but as branching. This diagram is in fact the very first introduction of the idea of branching time in logic (see Fig. 1).

Kripke's model presents time as branching from the present moment, 0, into possible futures (1, 2 or 3). This model includes future futures from the next moment as well as counterfactual moments (see Jakobsen & Øhrstrøm 2016 [8]; Øhrstrøm and Hasle 1995 [29]). From every future point in the system, there is a new subtree "consisting of its own present and future" (Kripke 1958). Such a view is ripe with metaphysical assumptions about time, but it does seem to accord well with natural language talk about time and especially future events (cf. Ploug and Øhrstrøm, 2012 [14]). Kripke used the word "tree" to describe the temporal structure in question, and he believed that such trees can give rise to a better representation of indeterminism than Prior's approach in *Time and Modality*.

Kripke's idea of branching time became extremely important for Prior's development of tense-logic in *PPF*. Kripke's idea involves future branching, but could branching pasts also be an interesting possibility? Prior

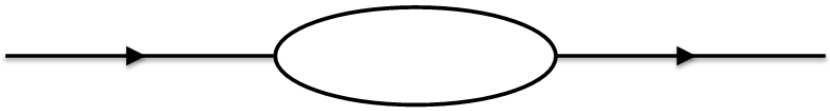

Figure 2: A branching time diagram with alternative possible immediate futures but only one ultimate future (*PPF*, p. 28).

found the idea of branching pasts conceivable from a formal point of view, but he found that the idea should be rejected for ontological and philosophical reasons – accepting that there is and should be an asymmetry between (fixed) past and (open future). His discussion of branching time in *PPF* includes diagram reproduced in Figure 2.

The diagram in Fig. 2 illustrates the idea of an ultimate future despite the occurrence of other developments "in between". Prior pointed out that such models were similar to views held by Marxists and some Christians. He rejected models of this kind. If there is going to be just one ultimate future, it cannot have different pasts. In his own words:

> But in general, I suspect, people are much less inclined to talk like this about the past than they are to say that there is no actual future but only various possible futures until we are past the dividing point. But if we don't thus say that the past (as opposed to the several possible pasts) is just wiped out at the end of the day, we cannot say that it will all be the same in a hundred years' time, no matter what happens in between; since one thing that will be different will be what, by then, has been the case. (*PPF*, p. 28)

For such reasons Prior insisted on backwards linearity. This idea can be formally expressed using the important work of Nico Cocchiarella (born 1933), who worked in the Priorean tradition and studied the axiomatics of tense-logic:[5]

[5]Nico Cocchiarella wrote his rather influential PhD thesis in 1965 on tense-logic.

(C4.1)[6] $(Pp \wedge Pq) \supset (P(p \wedge q) \vee P(p \wedge Pq) \vee P(Pp \wedge q))$

The intuition behind this axiom is that if p and q are both past, then each of them must have been present or past when the other was present, given that time is backwards linear. It is obvious that we could have discussed future linearity in terms of a formula of the same kind (see C4.2 in Prior 1967 p. 50).

One of Prior's great results in *PPF* is a thorough analysis of Cocchiarella's axiom. His analysis was based on the system K_t suggested by Lemmon in 1965 (*PPF*, p. 51, 176).

Prior presented K_t as an axiomatic extension of propositional logic characterized by the axioms using H and G as ~P~ and ~F~, respectively:

(Ax1) $G(p \supset q) \supset (Gp \supset Gq)$
(Ax2) $H(p \supset q) \supset (Hp \supset Hq)$
(Ax3) $PGp \supset p$
(Ax4) $FHp \supset p$

and the following rules of inference:

(RG) If $\vdash p$, then $\vdash Gp$
(RH) If $\vdash p$, then $\vdash Hp$

K_t has been called a "minimum" system (*PPF* p. 51) since it is difficult to imagine that there could be a tense-logical system that does not include K_t as a sub-system. An important result of Prior's analysis is that we can replace C4.1 in Cocchiarella's system with the following nice axiom:

(Ax5) $FPp \supset (Pp \vee p \vee Fp)$

In order to carry out this demonstration, only K_t together with the transitivity axiom ($PPp \supset Pp$) will be needed (see *PPF* pp. 50–55, 205–7). Cocchiarella's system is clearly stronger than this as it includes K_t as well as transitivity. Prior also proved that the transitivity axiom was equivalent to its mirror-image, $FFp \supset Fp$.

In order to investigate the problem of determinism within the framework of branching time, Prior introduced his so-called Ockhamistic system. Formally, the system should be conceived of as a temporal structure (TIME, $<$) in which TIME is the set of temporal moments, and $<$ is

[6] *PPF* p. 50.

a partial ordering of the members of TIME. We may define chronicles as linear and maximal subsets of TIME. Truth, in this context, is conceived as a function, π, defined on TIME $\times$ Φ, where Φ is the set of atomic, propositional symbols from which the propositional expressions of the logical system can be constructed. This means that for any pair, (t, q), of a temporal moment and a propositional constant of the logical language, a truth value, $\pi(t, q)$, is given as either 0 (false) or 1 (true) (see Jakobsen & Øhrstrøm, 2016 [8]). In Kripke's original system, truth is only related to the elements of TIME, i.e., the moments. In this case, the truth condition for the proposition $F\varphi$ can simply be written in this way (where φ is a well-formed formula as defined in the usual way for propositional calculus with tense and modal operators added):

$t \models F\varphi$ if there is a t' with $t < t'$, such that $t' \models \varphi$

In an Ockhamistic representation of time, we will have to evaluate the truth-value of tensed propositions relative to a chronicle of time. Truth-values in the Ockhamistic model can be laid down by recursive definitions:

$t, c \models q$ if q is an atomic, propositional symbol with $\pi(t, q) = 1$
$t, c \models \sim\varphi$ if it is not the case that $t, c \models \varphi$
$t, c \models F\varphi$ if there is a $t' \in c$ with $t < t'$, such that $t', c \models \varphi$
$t, c \models P\varphi$ if there is a $t' \in c$ with $t' < t$, such that $t', c \models \varphi$

The crucial property of the Ockhamistic model is that here, truth at a moment, t, depends on the choice of chronicle through t. This property can be illustrated by the diagram in Fig. 3.

In the Ockhamistic model, we can easily introduce a primitive possibility operator, $\Diamond$. The truth-condition of this operator can be defined as:

$t, c \models \Diamond\varphi$ if there is a chronicle c' with $t \in c'$ such that $t, c' \models \varphi$

Using this modal operator, it becomes clear that from an Ockhamistic point of view, there is a distinction between the three expressions $\Diamond Fq$, $\Box Fq$ and Fq, where $\Box$ is defined as $\sim\Diamond\sim$. This appears attractive from common sense and indeterministic perspectives. At any rate, there does seems to be a genuine three-way distinction in everyday English language if one considers an example like this:

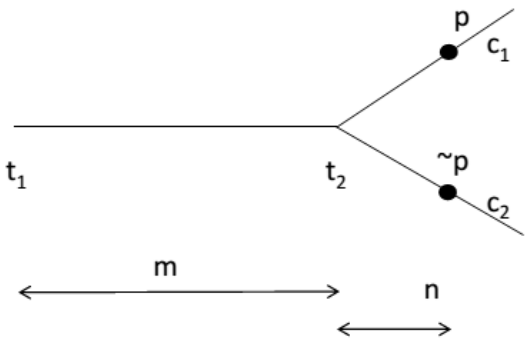

Figure 3: The Ockhamistic model of branching time where truth is relative to a moment on a chronicle. Fp is true at t_1 relative to the chronicle c_1, whereas $F{\sim}p$ is true at t_2 relative to the chronicle c_2.

a. Peter will go to Oxford tomorrow
b. Necessarily, Peter will go to Oxford tomorrow
   (or: It is a necessity that Peter will go to Oxford tomorrow)
c. Possibly, Peter will go to Oxford tomorrow
   (or: It is a possibility that Peter will go to Oxford tomorrow)

This immediate linguistic distinction is admittedly not compelling for the metaphysical choice of Ockhamism – everyday language usage can be misleading. Nonetheless, this affinity between Ockhamism and a rather immediate linguistic intuition is worth noting.

It also turns out that (D1) from the Master Argument does not hold in general, given an Ockhamistic model. In this way, the Ockhamist can avoid the fatalistic conclusion of the Diodorean Master Argument.

The "price" which the Ockhamist has to pay is that future truth depends on the chronicle. In this framework, there is no simple notion of truth at a moment!

Prior also introduced the so-called Peircean system of time. This model can in fact be seen as a fragment of the Ockhamistic system[7]. In the Peircean system, the future operator can be defined in terms of the

[7]Prior showed that it is also possible to present the Peircean system independently, i.e., without any reference to the Ockhamistic system.

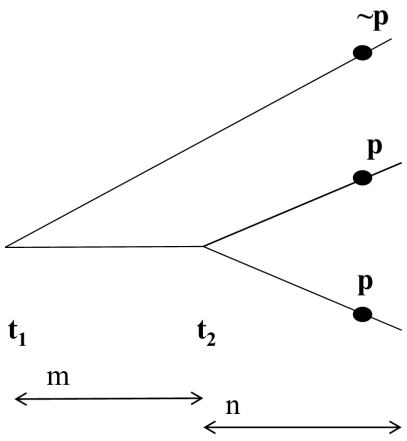

Figure 4: The Peircean model of branching time in which Fp it is plainly false at the past moment t_1, whereas it can be verified from the moment t_2.

Ockhamistic future:[8]

$$F_{\text{Peirce}} = \Box F_{\text{Ockham}}$$

This means that according to the Peircean, the future will be what the Ockhamist would call the necessary future. The Peircean can meaningfully speak about the possible future and the future (equivalent with the necessary future), but he will have no notion of the plain future. However, he can speak about truth at a moment (without referring to chronicles). The Peircean notion of the future can be illustrated as in Fig. 4.

Fig. 4 clearly shows that HFp does not follow from p, and hence, (D4) does not hold in the Peircean system. In this way, the Peircean can avoid the fatalism of the Diodorean Master Argument.

[8] In this system, we have to drop the equivalence of $\sim F \sim$ with G.

5 The tensed view of time

PPF opens with a discussion of McTaggart's important argument from 1908 against the reality of time. Peter Geach had made Prior aware of the importance of this argument. Prior admits that he had earlier thought of McTaggart "simply as an enemy" (*PPF* p. vi). However, although Prior still rejected the argument itself, he found McTaggart's introduction of the distinction between the A-series (past, present and future) and the B-series (earlier and later) very useful. The A-series describes time from the perspective of the dynamic present where time flows from the future into the past. Indeed, Prior later described the idea of time flowing most succinctly in what may be the last note he ever wrote. It was written in a hotel in Åndalsnes in Norway (or at least on the hotel's notepaper) shortly before he arrived in Trondheim, and with great likelihood is meant for a lecture he was going to give there. Here he stated (Prior 1969):

> Time flows on = All events are becoming more past... Whatever is or has been or will be the case, will have been the case. Can symbolise this as
>
> $\forall p : (p \vee Pp \vee Fp) \supset FPp$
>
> Time flows on, but once things get into the past they solidify & cannot be altered (Prior 1969)

The B series, in contrast, presents time from an eternal perspective as a tapestry with all the events of time spread out once and for all. Prior stated that McTaggart's analysis "presented what might be broadly called the phenomenology of time with singular accuracy" (*PPF*, p. 1, ff.). He also demonstrated that McTaggart's argument can be analysed in terms of tense-logic. According to the argument, time based on the tenses cannot be accepted since pastness, presentness and futurity characterize every moment of time, although the tenses are mutually exclusive. Prior found that his argument was mistaken. He pointed out that McTaggart's analysis simply demonstrated that any present event *will be* past and *has been* future. This does not give rise to any contradiction (as McTaggart thought). The present truth of the proposition p certainly neither excludes the truth of PFp nor the truth of FPp. In short, Prior showed that McTaggarts paradox could be solved by applying the

tense-logical approach, according to which all the statements in question should be considered and compared at the present moment.[9]

PPF contains a very strong emphasis on the significance and indeed the primacy of the tensed view of time. Thus Prior had to go against his good friend Jack Smart, who in his famous paper *The River of Time* (1949 [28]) had argued in favour of a B-series oriented view of time. This might be seen in light of the correspondence between Smart and Prior from 1954. In a letter to Prior dated 30 July, Smart claimed: "I don't believe in any metaphysical difference between past and future – in fact I believe the assertion of such a difference can be refuted". In his letter dated 9 August, Smart even maintained that Prior "tend[ed] to get philosophically misleading ideas" when using tense-logic. Smart suggested that we "can translate all sentences using 'past' and 'future' into sentences using 'earlier than this utterance' and 'later than this utterance'...". In *PPF*, Prior summarized his response to Smart. In fact, he accredited to Smart an important role in the process that led to him to the development of tense-logic. *The River of Time* was important since it "helped to make clear what had to be done" (*PPF*, p. 10). One important task was to show that the translation suggested by Smart is inadequate and must be rejected as a general principle. For this purpose, Prior considered the statement: "Eventually all speech will have come to an end". According to Smart's procedure, the translation of this statement would apparently be the self-contradictory proposition: "The end of all utterances is earlier than some utterance later than this one" (*PPF*, p. 12).

There might appear to be a tension between Prior's tensed view of time and his acceptance and further development of branching time diagrams. The problem is that the branching time structure may be conceived as rendering time as a B-oriented concept, i.e. time as a partially ordered set of moments. However, Prior emphasized that this is not how the idea of branching time should be understood. He admitted that the diagrams may be a useful way of stating the various claims regarding time (such as "Time will have an end" or "Time is circular"), but

[9] This view is closely linked with what was later called presentism, according to which only the present exists, in the sense that all claims about reality have to be stated as propositions that should be evaluated at the present moment. It can be argued that presentism provides the only effective response to McTaggart's argument (see Le Poidevin 1991, [9, p. 36]). Prior later developed his presentism in greater detail (Prior 1970 [22]; see Jakobsen 2011 [7]).

he also made it very clear that such claims should not be understood as attempts at explaining what time is – as seen from a metaphysical point of view. According to Prior, the various B-oriented discussions, including the various diagrams, are in fact just abbreviations of rather complex tense-logical statements (*PPF* p. 75).

6 The development of tense-logic after *Past, Present and Future*

Although Prior strongly emphasized the importance and qualities of tense-logic for a deeper study of time, he was also aware of the fact that there were some limitations to the tense-logical language presented so far. It turned out that there were statements on the possible properties of time which could be formulated in a B-oriented language but not in a simple tense-logical language – just for instance the irreflexivity of the earlier-later relation as in: $\forall t : \sim(t < t)$. Prior's answer to this problem was that "there is more to tense-logic than has so far been given, and certain enrichments of the symbolism can be expected to fill these gaps" (*PPF*, pp. 75–76). The enrichment that Prior had in mind was the addition of the so-called instant-propositions or world-states to tense-logic. This idea was introduced in chapter 5 of *PPF*, but as the chapter also makes clear some of the ideas go much further back, namely to joint work with Irish logician C.A. Meredith in the Fifties (see Copeland 2006 [3]) Such statements belong to a special class of propositions and correspond to – or perhaps rather, they replace - the temporal moments in the diagrams.

According to Prior, a world-state proposition functions as "an index of an instant" (*PPF*, p. 188–9). An instant-proposition (or a world-proposition) is only true once. For this reason, instant-propositions are very useful for the tense-logical understanding of the properties of branching time diagrams. Prior continued with the development of this enrichment of his tense-logic in his book *Papers of Time and Tense* (1968; 2003 [23]), which led to what is now called hybrid logic (see Blackburn 2000 [1]). Hybrid logic can be established in several ways, but essentially it unifies the operator-based language of tense-logic with the quantified language of the earlier-later relation. This development can be seen as "de-dramatizing" the tension between A-series and B-series, at least when it comes to the question of which language to use, but the meta-

physical difference between dynamical and static conceptions of time still persists.

In the late 1970s, Prior's temporal logic was introduced into computer science by Amir Pnueli (1941–2009), who later received the Turing Award for this work.[10] Temporal logic is now seen as a very important discipline in theoretical computer science. It seems that even while writing *PPF*, Prior had a inkling that his ideas might be useful to computer science. He wrote:

> The usefulness of systems of this sort does not depend on any serious metaphysical assumption that time *is* discrete; they are applicable in limited fields of discourse in which we are concerned only with what happens next in a sequence of discrete states, e.g. in the workings of a digital computer.
>
> [18, p. 67]

In theology, Prior's Peircean model has been seen as interesting. In his development of so-called open theism, Hasker (1998, [4, p. 64]) found inspiration from Prior's ideas.

While Prior's account of Ockhamism captured essential elements of his view on indeterminism and past facts about the future, it has been criticized as not accurately representing Ockham's view of time. According to Ockham, it does make sense to speak about the true contingent future, and hence, Prior's branching time diagram is not an accurate representation of what Ockham would affirm (See Øhrstrøm & Hasle 2015). In *Postulates for Tense-logic* (1966) published the year before *Past, Present and Future*, Prior did however consider an Ockhamistic system that included the notion of "a single *designated route* (sic) from left to right, taking one direction only at each fork". His idea was that Ockham's model should represent possible futures as well as an "actual course of event" (Prior 1966, p. 157). However, this discussion was not taken up in *PPF*, but the idea of a designated truth for the future was subsequently studied (cf. Øhrstrøm 2014 [31]). It has been pointed out that a version of the true future must also include a notion of counterfactual true futures. At any moment in time, including counterfactual moments, a "thin red line" designates what the true future is from that moment (see Øhrstrøm & Hasle 2015 [30]). An Ockham-like tense-logical model with a true future can be understood as a formalization of

[10] See http://amturing.acm.org

the medieval theologian Luis de Molina's theory of middle knowledge (1988 [11]). We know from Prior's early writings on theology that he rejected Molina's idea of middle knowledge. Although he found this idea interesting, he found that it was philosophically unrewarding. However, this view can certainly be questioned, and a further exploration of the Ockhamistic-Molinistic models of branching time should be carried out (see Øhrstrøm 2014 [31]; Jakobsen & Øhrstrøm 2016 [8]).

Rescher, Geach, Kenny, Kamp, Fine and others continued the development of tense-logic in the spirit of *PPF* in the years just after Prior's death in 1969. Many others would later contribute (see Øhrstrøm & Hasle 1995, 2015 [29, 30]). *PPF* should still be seen as a very significant book. It is clearly important for historical reasons. It has been the main tense-logic reference for 50 years as it contains some very interesting findings and results. Finally, the book defines a research agenda and paradigm that will be useful for anyone wishing to explore the tense-logical approach to the understanding of time.

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Time and Truth in "The Craft of Formal Logic": Prior's early temporal semantics born from reflexions on Diodorus and Boole

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Abstract

Arthur Prior's unpublished manuscript "The Craft of Formal Logic", written in 1950–51, contains his early ideas about time as a semantic concept. Years before he would publish his tense logic, Prior contemplated the construction of a semantic theory of propositional logic in which propositions are interpreted as functions of time instants. These ideas are born from reviewing historical material, and particularly from his analysis of Diodorus's conditional and Boole's propositional algebra. He suggests that 'P entails Q' could be expressed formally as '$\forall i(Pi{\rightarrow}Qi)$', where '$i$' stands for an instant of time, and 'Pi' stands for 'p is true at i'. On the pages of "The Craft", time is considered as a variant of possible worlds, both terms understood as alternative bases for a general semantic theory of propositional logic, as well as of modality, coined in quantificational terms.

Keywords: Arthur Prior, The Craft of Formal Logic, temporal semantics, time and truth, time and modality, history of tense logic

1 Introduction

Arthur Prior's first public exposition of temporal logic was in August 1954, when at a philosophy conference in Wellington he read "The Syn-

tax of Time Distinctions," the paper that contains his first tense systems[1]. By then he had already invented tense operators and described them in "Diodoran Modalities"[2], which, according to his own account[3], was finished by early 1954. But, his first lines in which he connects time and truth were written much earlier. Prior's unpublished manuscript "The Craft of Formal Logic"[4] reveals that his development of temporal semantics had begun at least three years before he delivered the Wellington address. "The Craft" was written in 1950–51 as a logic textbook that would tell the story of formal logic from Aristotle's syllogistic up to the modern axiomatic systems, with Prior constantly reminding the reader that the purpose of doing logic is its application to everyday reasoning. A large portion of the manuscript is devoted to the conditional and its interpretation, tracing down the best accounts of the intuitive meaning of "q follows from p" in the history. As Prior analysed Diodorus's conditional and Boole's propositional algebra, he linked them into a new and original concept of time as a semantic device. He suggested that 'P entails Q' could be expressed formally as '$\forall i(Pi{\rightarrow}Qi)$', where '$i$' stands for an instant of time, and 'Pi' stands for 'p is true at i'. We read on the pages of "The Craft" that he saw time as a variant of possible worlds, both terms treated as alternative bases for a general semantic theory of propositional logic, as well as of modality, coined in quantificational terms. These reflections carry the seed of his later tense logic given in Prior (1955) and Prior (1958).

2 The semantic aspirations of "The Craft"

When Prior began working on "The Craft of Formal Logic", his main interest in logic was the construction of a general semantic theory of propositional logic in quantificational terms. It seems that he set for himself as a task in his new manuscript to explore the best ways towards building such a theory. In the 1949 paper "Categoricals and hypotheticals in George Boole and his successors", he gives the reasons for

[1] This conference address was published as a journal article four years later, in 1958 in *Franciscan Studies* [9].

[2] "Diodoran Modalities" appeared in July 1955 in *The Philosophical Quarterly* [8].

[3] Prior (1967), p. 34 [10].

[4] "The Craft of Formal Logic" is kept in the Bodleian Library in Oxford, as part of the collection of Prior's manuscripts. It is available in digital form online, on the website of The Virtual Lab for Prior Studies. When quoting from it, I use the acronym CFL.

valuing this task. The goal of many generations of logicians had been to express truth-functions, or 'hypotheticals' (as they were historically called), in the traditional 'categorical', subject-predicate form, and then reduce all inference forms with conditionals (MPP, MTT, etc.) to the familiar categorical syllogism, which was for a long time considered a fundamental form of reasoning. Prior preferred to formulate propositional logic in those predicate terms, as Boole did, rather than the other way around (i.e. take propositional logic as fundamental, in the way of Johnson, Wittgenstein or Russell) because he believed that Boole did a better job than his modern successors in integrating both branches of logic "into a single deductive system," (Prior 1949, p. 190). What made the difference for Prior was the fact that Boole supplied his system with an appropriate semantic theory that could account for all types of propositions and inferences.

Boole carried out the formal unification of predicate and propositional logic by reinterpreting the symbols of his algebra either as classes or as propositions, respectively. To obtain predicate logic, Boole reinterpreted the symbols 'x', 'y', etc. as ranging over objects in a universe of objects. His 'first principle' was to "employ the symbol 1, or unity, to represent the Universe, ... comprehending every conceivable class of objects whether actually existing or not" (Boole 1847/1948, p. 15 [1]) and assume "that there *is* a Universe of conceptions and that each individual it contains either belongs to a proposed class or does not belong to it" (Boole, 1847/1948, p. 77–78). Prior sees the importance of this remark and bases his preference of Boole's semantic theory over Wittgenstein's or Johnson's on it (Prior 1949, p. 196 [5]). To obtain the propositional logic, Boole reinterpreted 'x', 'y', etc. as ranging over all the cases in which the corresponding proposition X, Y, etc. is true. To fix the domain of the propositional symbols, Boole reinterpreted "the symbol 1, which in this context he takes to mean a 'Universe' comprising, not the totality of 'things', but the totality of 'conceivable cases and conjunctures of circumstances'. He calls this the 'hypothetical Universe'" (CFL, pp. 460–1).

Prior agreed with the general framework of Boole's semantics, but found some fundamental flaws in his picture of the 'hypothetical Universe' that needed to be corrected. One of them concerned the semantic ambiguity of the symbols '1' and '0'. They are assigned the truth-values 'true' and 'false' respectively, but '1' is also identified with the

'hypothetical Universe', i.e. with the totality of circumstances in which a proposition is true, which gives the truth-values modal meanings. Behind this "good algebra" remarks Prior, lies "an inconsistency between the foundations and the superstructure of this system. For if the hypothetical Universe contains, as Boole at first says, 'all conceivable cases', the equation '$x = 1$', or '$1 - x = 0$', would seem to assert not merely that x is true but that its falsehood is inconceivable – that is, I take it, logically impossible" (CFL, p. 462). Another problem that Prior sees in Boole's theory concerns the number of universes required for evaluation. Prior noticed that the Universe used for evaluating one proposition is different from the Universe needed for evaluating two propositions. "Every proposition, or set of propositions, would seem... to have its own 'hypothetical universe'... but Boole sometimes speaks as if there were but one 'hypothetical Universe' for all propositions and sets of propositions," which for Prior is "a little bewildering" (CFL, pp. 461–2). These observations provoked Prior into constructing his own 'hypothetical Universe'.

> "What Boole was after might perhaps have been plainer if he had said something like this: There is one 'hypothetical Universe', which contains the totality of what we might call possibilities, or if you like, 'possible worlds'. We cannot give an exhaustive description of any one of these [possible worlds], but we can quite easily divide the whole collection of them into classes. Given the proposition X, we can divide them into (i) all the conceivable circumstances in which X would be true, these being selected by the symbol 'x'; and (ii) all those in which X would be false, these being selected by the symbol '$1 - x$'. Given a second proposition Y, we can subdivide each of these into further pair of classes of 'cases' – (i) into (a) the class of 'cases' in which X and Y are both true, selected by the symbol 'xy', and (b) the class of 'cases' in which X is true but Y is false, selected by the symbol '$x(1 - y)$'; and analogously with (ii). Every new proposition gives us a new set of subdivisions of the realm of possibilities. We can then take over without alteration the laws which govern the selection of items from the universe of 'things', and apply them to the selection of items from the universe of possibilities. Thus in the 'hypothetical Universe'

> as in the categorical, $xy = yx$ – the selection of all possible cases in which X is true, followed by the selection from these of the cases in which Y is true too, has the same result as the selection of the cases in which Y is true, followed by the selection from these of the cases in which X is true too. Either way, we arrive at the cases in which the compound 'Both X and Y' is true; and the law expresses the principle that 'Both X and Y' has the same logical force as 'Both Y and X' – any possible circumstance in which either is true, is one in which the other is true too." (CFL, pp. 462–3)

In "The Craft", Prior collected from the history of logic several technical devices that he thought were essential for 'crafting' a uniform formal logic. First, he recycled the ancient and medieval concept of propositions as propositional functions. According to Aristotle, 'Socrates is sitting down' may be true at one time and false at another, depending on when Socrates's sitting occurs. "'Socrates is sitting down' is thought of" says Prior, "as a diary entry, with a date, hour, minute and second beside it, and this date, etc. is part of the 'proposition'. Of the complete proposition thus formed, we may say that if it is true at all it is true for ever, and similarly if it is false" (CFL, p. 98). Another device that he borrowed is the 19^{th} century treatment of truth-functions as propositions about 'cases' of the constituent propositions, so that 'If P then Q', for example, is reformatted as 'All cases of P are cases of Q'. Typical for Whately, Jevons, Keynes, Peirce, Boole and others, this treatment originated in the work of Wallis (Wallis 1687 [11]), prompting Prior to refer to it as Wallis's method (CFL, p. 454). He was also inspired by Peirce's use of the formula '$a \longrightarrow b$' for both 'Every a is b' and 'If a then b'. Peirce's "symbol, '$\longrightarrow$' [was] designed to express indifferently the relation between the premises and conclusion of an inference, that between the antecedent and the consequent of a conditional, and that between the subject and predicate of a categorical" (CFL, p. 449). Finally, he regarded Russell's notion of 'formal implication', '$\forall x(fx \rightarrow gx)$' (Whitehead and Russell 1910 [12]), as an important invention towards achieving the unification, since its constituents can be viewed either as predicate functions or as propositional functions. Formal implication thus provided a neater syntactic link between the two logic branches. It was up to the interpretation of the 'subject' of the function 'fx' whether '$\forall x(fx \rightarrow gx)$' would be about properties or about propositions.

This last observation is Prior's focal interest in the "The Craft". If 'x' in the formal implication stands for individuals, the whole phrase represents the universal affirmative 'Every F is G'. He explores what interpretations of 'x' could turn formal implication into a conditional of Lewis's type. He finds that it would work well to that effect if 'x' is taken to stand for 'cases', 'possible worlds', 'possible states of affairs' or 'times'. He continued examining this idea in some of his post-Craft publications, testing the application of the modal notions in the papers like "In what sense is modal logic many valued?"[5] (where 'x' is interpreted as 'possible states of affairs') and the application of the temporal notions in his two 'temporal' papers created in 1954, Prior (1955) and Prior (1958).

3 Temporal interpretation of Diodorus's conditional

Prior labels Diodorus's conditional as the right way to understand the meaning of the consequent's 'following' from its antecedent, while avoiding the paradoxes of the material implication. Diodorus himself had apparently warned against the paradoxes of material implication, advocated by his contemporary Philo, by saying that the "statement 'If it is day, I am conversing' would also count as true conditional by Philonian standards, if uttered at the right time (if uttered at night, whether I am then conversing or not; or if uttered when I am conversing, whether by night or by day); but 'I am conversing' would not generally be said to 'follow' from 'It is day'" (CFL, p. 408). Prior notes as an important point that the right interpretation of the conditional should make the time of utterance irrelevant for whether the consequent 'follows' from the antecedent or not.

In that sense, he sees Diodorus's definition as a step in the right direction. According to it, "a true conditional is one which 'neither was nor is capable of beginning with a truth and ending with a falsehood'" (CFL, p. 409). Prior gives two analyses of it. First, he understands it as a modal one, identical to Lewis's strict implication: "There is a suggestion here that 'If P then Q' means not merely that P is not in fact true without Q being true, but that P *cannot* be true without Q being true"

[5] Published in June 1952, written c. late 1951 to early 1952 [7].

(CFL, p. 409). Here Prior makes an early use of his modal apparatus, set up later in the manuscript in the chapter "On modality", by which he distinguishes between the actual, or what is in fact true, and the possible/necessary, or what can/must be true.[6] This modal interpretation is clearly quantificational, impossibility being derived from the phrase 'neither was nor is capable', although the derivation is not explicit. In the second analysis, Prior takes the liberty to reformulate Diodorus, admitting the possibility that he is not historically accurate.

> "But there is another possible interpretation of Diodorus's position which, though not a very likely one, is worth considering because of the interest attaching to its modern counterpart. Like the ancients generally, Diodorus thought of the truth-value of propositions like 'It is day' as altering with the 'time of predication'; and in his criticism of Philo he lays some stress on the point that the Philonian definition makes the truth of conditionals also (at least in some cases) depend on the time at which they are uttered. We might therefore take the position he is opposing to Philo's to be that 'If P then Q' is true if and only if there never have been and never will be times at which P is true and Q simultaneously false. The Diodoran 'following', on this interpretation, becomes something very like the kind of implication which Lord Russell calls, not 'material', but 'formal'. This is a relation, not between genuine propositions with a fixed truth or falsity, but between 'propositional functions', expressions like 'that it is human', which may be true of some subjects and false of others. Thus that a thing is human 'formally implies' that it is mortal, because there is no subject of which the former is true without that latter being true of it also. The 'subjects' which Diodorus considers are times; and his view might be that 'If it is day it is a light' is a true conditional because there is no time of which 'that it is (now) day' is true while 'that it is (now) light' is false." (CFL, p. 409–10)

The modern counterpart that Prior mentions is obviously Russell's 'formal implication', which connects predicates. By emphasising that in the ancient understanding of propositions, the propositions alter their

[6] See Markoska-Cubrinovska (2016), p. 3462 [4].

truth-value with the 'time of predication', Prior suggests that they can be viewed as propositional functions of time. Thus, 'p' can be understood as 'p at i', or 'Pi'. Propositions reduced to propositional functions have the same syntactic form as predicates and fit in the format of Russell's formal implication. The conditional becomes 'If Pi then Qi', connecting propositional functions. Prior's reformulation of Diodorus's conditional as true iff there is no time i at which P is true and Q simultaneously false, binds the propositional functions with the universal closure of the temporal variable: 'For every i, if Pi then Qi'. If we take Diodorus's conditional to be a formal implication with propositional functions over times, its formal expression would be '$\forall i(Pi \rightarrow Qi)$'. In negative terms, there is no time at which P is true and Q false, the formulation would be '$-\exists i(Pi\& -Qi)$'. This corresponds to Lewis's definition of the 'strict implication' (Lewis and Langford 1932 [3]), which Prior comments in the following way:

> "The more probable interpretation of Diodorus, however, it that which assimilates his conception of 'following' to what Professor C. I. Lewis in our day has called 'strict' implication, which holds when the combination of the truth of the first proposition with the falsity of the second is not only false but logically impossible, e.g. when it is a 'contradiction' in Wittgensteinian sense. Or to put it another way, 'strict' implication holds when the material implication of the second proposition by the first is not only true but logically necessary, e.g. when it is a Wittgensteinian 'tautology'." (CFL, pp. 410–11)

At this stage of the manuscript, Prior does not elaborate on the obvious correspondence between the modality of the strict implication and the temporal universality of Diodoran conditional. Later, in the chapter "On modality" (CFL, pp. 720–760), he will develop an explicit quantificational theory of modality, based on the previously observed parallelism between the modal and quantificational concepts. Also, in Prior (1952) he will construct a formal proof of the equivalence between the strict implication and the formal implication using as the 'subject' of quantification, the notion of 'possible states of affairs'.

4 The course of Time as a propositional Universe

In his early 'temporal' papers (Prior 1955) and (Prior 1958), Prior implicitly assumes time as the domain that supplies values for the individual variables. He discusses this assumption explicitly in "The Craft", once again inspired by Boole. After Boole introduced the 'hypothetical Universe' of 'cases' in *The Mathematical Analysis of Logic* (Boole 1847), he made another attempt to construct an appropriate domain for the symbols of the propositional calculus. In *The Laws of Thought* (Boole 1854 [2]), he identified the 'hypothetical Universe' with the 'entire course of Time', and substituted the 'cases of propositions being true' with 'times at which propositions are true'. Here he used "the symbol x to represent the selection of the times at which the proposition X is true, and $1 - x$ the selection of the times at which it is false. '$x = 1$' on this interpretation asserts that X is true at all times, i.e. true simpliciter, '$x = 0$' that it is at all times false, '$xy = 0$' that X and Y are never true together, and so on." The conditional "'If X then Y' he now takes to mean that any time at which X is true is one at which Y is true" (CFL, p. 466). The 'course of Time' provides the same type of quantificational interpretation of the propositional expressions as the previous 'hypothetical Universe'. The reading of the conditional is: "The times at which X is true are a sub-class of the times at which Y is true" (Boole 1854/2017, p. 127). Prior says that this interpretation of the conditional is identical to his own temporal version of Diodorus's conditional given on p. 409 of "The Craft". Both temporal interpretations, Boole's as well as his, rely on the so-called 'ancient' view of propositions as propositional functions, in this case, as functions of time. And, as Prior admits, "most modern logicians do not favour this mixing of Truth with Time" (CFL, p. 466). He anticipates that to many of them the temporal domain may look like an 'awkward element'. Nevertheless, it is designed to enable fulfilling the difficult task that he (as Boole before him) had chosen for his project: to construct a general semantic theory for both predicate and propositional logic, a task that he believed was otherwise unachievable.

> "What stands most in the way of reducing hypotheticals to categoricals is that whereas 'Every X is Y' asserts that every instance of its subject-term *is* an instance of its predicate-term, 'If X then Y' does not assert that the proposition X *is* the proposition Y, but only that the truth of the first involves

> the truth of the second. The problem is to express this assertion of concomitant truths as an assertion of identity; and it is this problem to which Boole sees a solution in making the conditional assert that any time at which X is true 'is' one at which Y is. The times are identical even though the propositions are not. Wallis's 'cases' are of course designed to meet the same difficulty, and one of Boole's remarks (Boole 1854/2017, p. 136) suggests that he regards his own (second) theory not as a complete abandonment of Wallis's, but rather as a clearer statement of what we must take a 'case' to be." (CFL, p. 466 [6])

Just as 'time at which X is true' is a variant of 'case in which X is true', so is the course of time an alternative to the propositional universe of possible worlds. In 1951 Prior concluded that both concepts are worth investigating.

5 Conclusion

Prior's unpublished manuscript "The Craft of Formal Logic", written in 1950–51, reveals that his development of temporal semantics had begun at least three years before he first publicised his tense logic. Prior's main goal in "The Craft" was to set the foundations for constructing a general semantic theory of propositional and predicate logic in quantificational terms. After reviewing a number of theories and solutions from the history of logic, he adopted the view that the domain for the propositional symbols should be analogous to that for predicate symbols, a Universe of 'possible worlds' or 'cases' in which propositions are true. Inspired by Diodorus and Boole, he concluded that the course of time could be considered as an alternative propositional domain. The elements in this domain are times, more precisely, instants of time, while the propositions are constructed as propositional functions of time instants.

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C.A. Meredith, A.N. Prior, and Possible Worlds

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Abstract

Arthur Prior and Carew Meredith cooperated on the formulation of several systems of logic. The cooperation was so close that on the basis of their joint work, they are both considered to be precursors of possible worlds semantics. However, their concept of possible worlds, their understanding of the relevant formal representations and indeed their general approach to modal logic considerably differed. These differences should be pointed out in order to more precisely appreciate the contribution of each of these authors. To neglect the differences could cause the misinterpretation of Meredith's and Prior's work. On the one hand, it might cause corruption of Meredith's system of logic and lead to paradoxes, as Prior pointed out in 'Modal Logic with Functorial Variables and a Contingent Constant'. On the other hand, considering Prior as a mere follower of Meredith could cause an underestimation of Prior's originality and contribution to this field.

Keywords: C. A. Meredith, A. N. Prior, Possible worlds, Possible worlds semantics, Modal logic, Many-valued logic

1 Introduction

Although a proof of consistency is a highly desirable result for a system of logic, such a proof is not always uncontroversial. Arthur Prior (1967, 77 [35]) pointed out this issue in '*Logic of Successive World-States*', chapter V of *Past, Present and Future*.[1] Namely, he stressed that Smiley's proof did show a consistency of most systems of tense and modal logic, but modal operators appeared in the light of this proof trivialised, and modal calculi are insufficiently characterised by them. Therefore, the proof raised the need for a de-trivialising of systems of modal logic. There are several solutions to the problem. Ivo Thomas and Jan Łukasiewicz (1970b, 353 [9]) favoured the reversed turnstile to indicate that what follows is not a thesis of the system. Another solution is propositional quantification in systems of modal logic which was represented for instance by Saul Kripke (1959 [7]). Lastly, Prior (1967, 77–78 [35]) also presented his solution which consists in introducing a propositional variable 'a' with certain decisive properties.[2] Prior pointed out that the idea could be found in Meredith's system of modal logic in which it figured, albeit as a constant called 'n'.

Prior did not deal with the variable 'a' for the first time in chapter V of *Past, Present and Future*, the '*Logic of Successive World-States*'. It was already introduced in Prior's and Meredith's joint paper '*Interpretations of Different Modal Logics in the "Property Calculus"*', published in 1996 [40] but originally written in 1956 and at the time distributed in mimeographed form. Their joint introduction of the propositional variable 'a' certainly suggests a relation between this 'a' and Meredith's 'n'. Additionally, and not least on account of this paper, Meredith and Prior are considered to be precursors of possible worlds semantics, as was extensively argued in (Copeland, 2006 [3]). Copeland's argument was to some extent dependent on the relation between Prior's 'a' and Meredith's 'n'. In the paper '*Interpretations of Different Modal Logics in the "Property Calculus"*', written three years before the publication of Kripke's '*A*

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[2]Even though Prior described 'a' as a constant in V. chapter of *Past, Present and Future*, he later identified it with a variable (see Prior, 2003b, 183 [38]). It also acts as a variable in his systems of logic (see, e.g., Prior 1967, 90 [35]). Therefore, Prior's 'a' will be labelled as a variable elsewhere in this paper.

Completeness Theorem in Modal Logic', Prior and Meredith introduced a system of logic later named U-calculus where variables 'a', 'b', and 'c' are bound by a binary operator 'U'. Neither the operator nor the variables are, however, interpreted in the paper but as already noted Prior later claimed the similarity between the variables and Meredith's constant 'n', namely in chapter V of *Past, Present and Future*, as was mentioned in a previous paragraph. Moreover, as demonstrated in (Copeland 2006), the 'U' arguably anticipates Kripke's accessibility relation. The interpretation of 'U' will be discussed more later.

However, the translation from 'a' to 'n' is not as straightforward as it appears to be from previous claims. Namely, it is not certain that Prior and Meredith shared a similar approach to modal logic. There are at least two different approaches to systems of logic which deal with future contingents. They are firstly systems of many-valued logic which follow Łukasiewicz's (1970a, 125–127 [8]) rejection of the rule of bivalence and which contain three or more truth-values. Łukasiewicz's solution thus is extensional and plainly truth-functional, but of course at the cost of the complications of defining the truth-functions which many-valued logic introduces. Differing decisively from Łukasiewicz's solution, the second approach retains bivalence and 'instead' consists in the enlargement of semantics through the introduction of intensional systems of logics. The latter approach is also linked with possible worlds semantics. While Prior in his later works undoubtedly discussed possible worlds and his systems of logic were intensional, Meredith's approach is more unclear since Meredith did very little to explain it in his papers. There are certain indications that it might differ from Prior's view. The first Meredith's system of modal logic was many-valued and in general, Meredith was deeply influenced by Łukasiewicz.

The aim of this paper is to point out certain differences in their systems of logic and even question whether Prior's 'a' and Meredith 'n' are translatable into one-another. In order to introduce the issue, Meredith's systems of logic, his constant 'n', and his overall approach to logic will be presented. Secondly, Prior's 'a' will be discussed. The chapter will also touch on his critique of Meredith's system of modal logic. The final chapter includes arguments that support the view that there are several differences between Meredith's 'n' and Prior's 'a' and reasons why these differences are important.

2 Meredith's Systems of Modal Logic

Meredith was originally a mathematician. As he switched from mathematics to logic, he demonstrated his excellence in the formal logic. David Meredith (1977, 514–516 [22]), C.A. Meredith's cousin, reported that a lot of Meredith's papers, which Prior published, arose as Meredith's response to logical queries of Meredith's colleagues (cf. appendix). In contrast to the formalism, philosophical implications were nearly not discussed in Meredith's published works. Meredith had taken up formal logic even before Łukasiewicz's arrival to Ireland shortly after World War II, but his work was henceforth deeply influenced by this Polish logician, who spent his last years until his death in 1956 in Dublin where Meredith lived. It is worth mentioning this influence in general, since not only Meredith's systems of modal logic – which are in fact only a minor part of his work – carry vestiges of Łukasiewicz's influence. Indeed this influence spread through almost all (or maybe all) of Meredith's published work. Meredith is acknowledged primarily as an author of condensed detachment, which helped him to abbreviate proofs (see Kalman 1983, 443 [6]). The detachment operations were for the first time introduced to Meredith by Łukasiewicz (D. Meredith 1977, 514 [22]). The rule of detachment was used for the shortening of axioms, which was a central endeavour among Łukasiewicz and his students (see Skolimowski 1967, 61 [42]). Meredith's application of Łukasiewicz's approach was so successful that he was able to find shorter axioms than Łukasiewicz himself. (see Church 1951, 229 [2]).

There are two systems of modal logic in Meredith's work.[3] The system $(\supset, \Box, 0, n, \delta, p)$ was introduced by Meredith in 1953 and published in a joint paper with Prior in 1965 (Meredith and Prior 1965 [20]).[4] The constant 'n' appeared for the first time in this system of logic. It represents 'the world' and also stands for 'contingently true', i.e., true in this world but false in another world.[5] However, it also takes on a sec-

[3]Despite several differences, both systems are based on Meredith's work on the calculus of properties (Meredith and Prior 1965, 102 [20]; Prior and Meredith 1996, 133–134 [40]). The calculus of properties appeared for the first time in the paper '*Ein erweiterter Klassenkalkül*', which was written by Mordechaj Wajsberg, Łukasiewicz's student in Warsaw. Łukasiewicz recommended this paper to Meredith (see Copeland 2006, 379).

[4]It is worth mentioning that under the title '*Note on my modal system*' in Prior's archive [13] could be found Meredith's paper which deals with this system of logic.

[5]False in every other world, if there are more than two – see the remarks below on having three or more possible worlds. Meredith investigates various scenarios, the

ond meaning, wherein 'n' acts as a truth-value – as in the truth table below (Table 1). Moreover, 'n' has a counterpart in '$\dot{n}$', which means false in this world but true in another world, i.e. contingently false. The constants 'n' and '$\dot{n}$' were originally introduced as constants for a many-valued system of modal logic. The axioms of the system are:

1. $\Box[\delta[(p \supset 0) \supset (q \supset r)] \supset \delta[(r \supset p) \supset (q \supset p)]]$[6]
2. $\Box p \supset [\delta(p \supset q) \supset \delta q]$
3. $\delta(0) \supset [\delta(0 \supset 0) \supset \delta(\Box p)]$
4. n
5. $p \supset \Box(n \supset p)$
6. $\Box n \supset p$ (Meredith and Prior 1965, 103 [20])

Despite being constant, 'n' is also an axiom in this system of modal logic. In addition, two other axioms which contain 'n' characterise its function in the system. As is pointed out in *Computations and Speculations* (Meredith and Prior 1962, 118 [18]; see Appendix), the axiom $p \supset \Box(n \supset p)$ claims that any proposition which is true in the system is necessarily implied by 'n' and the axiom $\Box n \supset p$ means that if 'n' is necessary it could imply any proposition. Nonetheless, '$\Box n$' is not a theorem of the system.

The smallest matrix satisfying the axioms could be defined as the table (Table 1) for the implication and '$\Box$'.

Since 'n' and '$\dot{n}$' are truth-values, this Meredith system of modal logic is a many-valued system. The semantics of the system is based on truth-values. Although 'n' was described by Meredith as 'the world' or 'the possible world', it is firstly and mostly the truth-value. In the previously defined matrix, it could be described as consisting of two truth-values '1' for this world and '0' for another world, e.g., $(1, 0)$. Consequently, it is argued in *Computations and Speculations* (Meredith and Prior 1962 [18]) that the minimal number of truth values of the system is

details of which go beyond the purpose of this paper.

[6] 'δ', 'ε' and 'ζ' are one-placed propositional functors (see Simons 2017 [41]) from formulas into truth-values. Their introduction allowed the shortening of axioms, which was discussed in a previous paragraph, and they are not vital to the understanding of this paper (even though the shortening of axioms was the most crucial of all endeavours to Meredith). Observe that the axioms can be read 'disregarding' the 'δ', i.e. considering the trivial case where a formula is substituted with itself – i.e. you may 'throw away' 'δ' simply by replacing its argument with itself. The constants '0', '1', 'n', '$\dot{n}$' stand for the defined truth-values.

Table 1: The smallest matrix satisfying the axioms of Meredith's system $(\supset, \Box, 0, n, \delta, p)$ from Prior's *Past, Present and Future* (see Prior 1967, p. 78 [35]).

$\supset$	1	n	$\dot{n}$	0	$\Box$
1	1	n	$\dot{n}$	0	1
n	1	1	$\dot{n}$	$\dot{n}$	0
$\dot{n}$	1	n	1	n	0
0	1	1	1	1	0

four, i.e. 1, 0, n, and $\dot{n}$. If 'n' is intended to be clearly distinguished from other contingent propositions, there should be at least three possible worlds and eight truth values (see Meredith and Prior 1962, 119 [18]). In this way 'n' could be differentiated from other contingent propositions which are true in more than the actual world. There could be more possible worlds and more truth values. In these cases, 'n' appears as a sequence of truth values, namely true in the actual world and false in others i.e. '1, 0, 0, ..., 0' sequence of truth values. For this reason, Meredith argues: "'n', though true, is next to absolute falsum, '$n\supset 0$', though false, is next to absolute verum." (Meredith and Prior 1965, 108 [20]).

The second system of modal logic to which Meredith contributed was U-calculus, which was introduced in 1956 in a joint paper with Prior '*Interpretations of Different Modal Logics in the "Property Calculus"*'. The system contains variables 'a', 'b', and 'c', which were not interpreted in the paper, but Prior identified them later with possible worlds (see Prior 1962, 36 [32]) and time instants (see Prior 1967, 88 [35]). Since this system of logic was primarily discussed by Prior, it will be introduced in the next chapter.

3 Prior's Concept of Possible Worlds

While Meredith's system of modal logic is many-valued, Prior was a keen proponent of intensional logic. Therefore, he discussed intensively possible worlds in his works and had a certain concept of them. This was, however, not quite the case at the earlier period of his career during which he started developing his interest in tempo-modal logic (the early Fifties). His view on modal logic developed during his lifetime. In

the early Fifties, Prior appreciated also Łukasiewicz's many-valued approach to modal logic and future contingents,[7] but he turned to intensional logic later, especially when he began his development of modern temporal logic (see Prior 1955a [28]).

As was mentioned in a previous chapter, Prior's 'a' was introduced in the joint paper with Meredith in 1956. Prior interpreted this variable and the entire system of logic to which it belongs in 1962 in his papers '*Possible Worlds*' and '*Tense-Logic and the Continuity of Time*'. All three of the papers in question deal with U-calculus,[8] the system of logic based on the introduction of the operator 'U'. This operator is in '*Possible Worlds*' and '*Tense-Logic and the Continuity of Time*' described as an operator which states accessibility between possible worlds. 'Uab' means the move (or the jump as was suggested by Geach to Prior) from the possible world 'a' to the possible world 'b'. It could be also interpreted as asserting that the possible world 'b' could be reached from the possible world 'a'. (Prior 1962b, 36 [32]; Prior 1962c, 140 [33]).[9] In '*Tense-Logic and the Continuity of Time*', Prior (1962c, 140 [33]) suggested a temporal interpretation of U-calculus, when he interpreted 'Uab' as 'b' being the future outcome of 'a'. This interpretation is close to the temporal interpretation of U-calculus, where 'Uab' means 'The instant a is earlier than the instant b' (see Prior 2003a, 118 [37]).

B. Jack Copeland (2006, 378–380 [3]) emphasises that the papers '*Possible Worlds*' and '*Tense-Logic and the Continuity of Time*' are unique

[7] This fact is evident from Prior's appraisal of Łukasiewicz's system of modal logic in papers, which were published in those years (see Prior, 1952a; Prior 1952b; Prior 1953a; Prior 1953b [24, 25, 26]).

[8] The origins of U-calculus are unclear. Copeland (2006, 377–378 [3]) argues that it was based on l-calculus, which Prior introduced previously. There is also a 'U' operator which was introduced by Jerzy Łoś in the paper '*Foundations of the Methodological Analysis of Mill's Canons*'. Prior was acquainted with this paper by Henry Hiż's review [5] and discussed this operator in his *Time and Modality*. The formula 'Ut_1p_1' means 'p_1 is satisfied in the t_1', where 'p_1' stands for a proposition and 't_1' can be understood as a time instant. Both variables belong to the semantical category of propositions (see Hiż 1951, 58–59 [5]; Prior 1957, 19–28 [30]). However, there is no direct reference to Łoś in Prior's discussion of U-calculus. Prior (1967, 42 [35]) argued that U-calculus was formalised by Meredith.

[9] The closeness to Kripke's accessibility relation in Kripke 1959 [7] is obvious. In so far as these understandings were also present, albeit implicitly, in Meredith and Prior's 1956 paper (*Interpretations of Different Modal Logics in the 'Property Calculus'*, published 1996 [40]) it is fair to say that they anticipated Kripke semantics by several years, as Copeland argues in (Copeland 2006 [3]).

in their presentation of possible worlds semantics. Published soon after Kripke's famous paper '*A Completeness Theorem in Modal Logic*' (Kripke 1959 [7]), they made no reference to this paper, even though Prior as a reviewer of it was obviously aware of its publication as well as its content. This apparent omission might be caused by the fact that the two papers in question are based on a previously written paper '*Interpretations of Different Modal Logics in the "Property Calculus"*' which Prior wrote in cooperation with Meredith in 1956.[10]

The papers discussed so far were not the only papers dealing with modal logic which Prior and Meredith wrote together. In 1965, the paper '*Modal Logic with Functorial Variables and a Contingent Constant*' was published, in which Meredith's systems of modal logic and Prior's discussion of them appear. Prior acknowledged that he was influenced by Meredith's system of logic in his previous papers, namely by Meredith's constant 'n' which in various contexts is interpreted to stand for 'possibility', 'the world', or the Wittgensteinian 'the world is the case', or plainly a truth-value (but then in line with the previously mentioned understandings). Nonetheless, in the discussion of Meredith's system in this paper Prior (1965, 100 [20]) argued: 'Formally, the system is elegant and ingenious; philosophically, it may well give rise to misgivings.' Prior demonstrated that the identification of the constant 'n' with a possible world could lead to a problem with propositional identity, which is so serious that Prior claimed that there could be no such proposition as Meredith's 'n' (Meredith and Prior 1965, 100–101 [20]). Prior (1967, 77–82 [35]) further refined and enlarged his criticism in the previously mentioned '*Logic of Successive World-States*' (chapter V in *Past, Present, and Future*).

Instead of a constant 'n', Prior introduced world-propositions, which are formed by two operators 'W' and 'Q'. While 'Wp' means 'p comprehends all truths' (Meredith and Prior 1965, 101 [20]), 'Qp' stands for 'p is the totality of truth at some time' (Prior 1967, 80 [35]). The operators are defined as:

$$\begin{aligned} Wp &\stackrel{\text{def}}{=} p \wedge \forall q\,[(q \supset \Box(p \supset q)] \\ Qp &\stackrel{\text{def}}{=} \Diamond p \wedge \forall q\,[\Box(p \supset q) \vee \Box(p \supset \neg q)] \end{aligned}$$

Prior (1967, 79 [35]) claimed that these functors were able to prevent

[10] The paper was, however, not published during their lifetime. It was discovered by Copeland and published by him in 1996 [40].

trivialisation of modal logic and therefore they could replace the variable 'a' or Meredith's constant 'n'. Further in '*Logic of Successive World-States*', Prior (1967, 88–92 [35]) suggested the translation between this calculus and U-calculus. He followed this up in 1968 in the chapter '*Tense Logic and the Logic of Earlier and Later*' in *Papers on Time and Tense*, where the possibilities of translation are fully explored as '*Four Grades of Tense Logical Involvement*' (Prior 2003a [37]). The operators 'W' and 'Q' led to the postulation of Prior's world-propositions and instant-propositions. World-propositions (and instant-propositions) are according to Prior the maximal conjunct of propositions. It means that if any proposition which is not implied by this conjunct is added to it by conjunction a contradiction appears. World-propositions represent Prior's concept of possible worlds respectively time instants and at the same time they are ingeniously suited to Prior's nominalism. They allowed him to claim that there are no possible worlds as real existent entities but only propositions bound by the propositional quantifiers (see Meredith and Prior 1965, 99–102 [20]) (and this, in turn, strengthened one of his most crucial tense-logical points, the idea that instants do not exist in their own right but are to be understood as "logical constructions'').[11]

4 'a' and 'n' as Possible Worlds

There are certain similarities between Prior's 'a' and Meredith's 'n'. Prior also seemed to derive the inspiration for his variable 'a' from Meredith's constant 'n'. However, the aim of this chapter is to point out several reasons why a translation between Prior's 'a' and Meredith's 'n' is not straightforward.

Firstly, it is not certain to which of two traditions of modal logic Meredith belonged, as was mentioned previously. On the one hand, Meredith was deeply influenced by Łukasiewicz after the latter's appointment to Ireland, and Meredith took part in the development of Łukasiewicz's systems of logic. On the other hand, his important works dealing with modal logic were written in cooperation with Prior, who

[11] Prior said this more or less directly in many places. For example, in chapter V of *PPF* he argues that time instants consist of propositions, and in (2003a [37]) he strongly and thoroughly lays out the same idea. In what may well be the last note he ever wrote (Prior 1969 [36]), in a hotel in Ånsdalsnes in Norway shortly before he arrived in Trondheim where he died, he wrote most succinctly: "What is time? Time is a logical construction."

represented the intensional approach to modal logic. In addition, there is this certain concept of possible worlds in Meredith's works. The decision as to where Meredith really stood is crucial since the traditions differ radically in their approach to possible worlds. There are in our opinion certain features which indicate that Meredith approach to modal logic belongs more to Łukasiewicz's tradition than to Prior's.

As already mentioned there are features which suggest a closeness between Prior's 'a' and Meredith's 'n', not least the simple fact that the variable 'a' and U-calculus were introduced in Prior and Meredith's joint paper '*Interpretations of Different Modal Logics in the "Property Calculus"*'. The question is, however, to what extent U-calculus was principally Meredith's system, or to what extent he contributed to the development of it. Namely, there could be a close similarity between 'a' and 'n', if Meredith's considered U-calculus as a system of modal logic and variables 'a', 'b', 'c' possible worlds. It was already mentioned in this paper that Prior's interpretation of this system was linked with possible worlds semantics. In *Past, Present and Future* he however also reports:

> In some notes made in 1956, C. A. Meredith related modal logic to what he called the 'property calculus' in the following way: Suppose we use a, b, c, etc., as name-variables, and U as a constant 2-place predicate. What the sentence-form Uab means does not matter. (Prior 1967, 42).

It seems that Prior acknowledged Meredith to be the originator of U-calculus – indeed in all his remarks regarding U-calculus, Prior claimed that it was Meredith's formalisation. However, Meredith's interpretation of the system, if there was any, is unclear. Although Prior identified the variables 'a', 'b' and 'c' with possible worlds, the quotation seems to imply that 'a', 'b' and 'c' were not interpreted as possible worlds by Meredith.[12] Moreover, in spite of the fact that Prior attributed the invention of U-calculus to Meredith's formalisation, he did not acknowledge him as an author of possible worlds semantics – and Prior was always prepared to acknowledge any contribution which a colleague made to his own work (e.g., Øhrstrøm and Hasle 1995, 171 [23]). – But as ob-

[12]The interpretation appears to be closer to the operators in Leśniewski's system of logic. Nevertheless, there is no evidence that he has this system of logic in mind here and Wajsberg's original paper also referred to a different source of inspiration, namely the calculus of David Hilbert and Wilhelm Ackermann (Wajsberg 1933, 113 [43]).

served, when Prior discussed Meredith's possible worlds it is always linked to the constant 'n'.

A variable 'a' is mentioned in *Computations and Speculations*, in which is written:

> ... n is represented by the property of being identical with a selected object a, formulae which express properties of a as well as formulae which express properties of all objects being taken as theorems. This is analogous to the use of matrices in which value n or 'true in n only', is designated as well as the value 'true in all worlds'.
>
> (Meredith and Prior 1962, 121 [18])

Nonetheless, there is no suggestion that this 'a' is identified with possible worlds. It seems from this description that the variables 'a', 'b', and 'c' stand for objects according to Meredith.

In addition, it is not exactly clear if Meredith had any elaborate philosophical concept of possible worlds as metaphysical entities. Meredith may have had certain ontological views on possible worlds, but they never occurred in his papers or even in his correspondence to Prior. However Prior reported certain views on this subject which attribute some metaphysical considerations or even views to Meredith. Namely:

> The system $(C, \Gamma, 0, n, \delta, p)$ introduces the more original feature of a constant n to represent "the world" in the Wittgensteinian sense of "everything that is the case."
>
> (Meredith and Prior 1965, 99 [20]).

> For all his virtuosity in these formal manipulations, and his training being mathematical, Meredith likes to do philosophical jobs with his logic too. He has a modal system with a contingent constant n for 'the world' in Wittgenstein's (Tractatus) sense of 'everything that is the case' – the logical product of all true propositions. Developing Wittgenstein's other Tractatus statement that 'The world is the totality of facts, not of things' in the light of his insistence (e.g. in the Notebook 1914–16, p.93) that 'facts cannot be named' we may say that 'the world' is not the biggest nameable object, but the maximum that can be truly said, and so must be expressed

> by a proposition. Meredith's $\underline{\text{n}}$, put to this use, has such laws as $\underline{\text{CpLCnp}}$ $[p \supset \Box(n \supset p)]$ – any true proposition is strictly implied by $\underline{\text{n}}$, since it is a conjunct of it. And a possible world is a proposition which, though possibly true, says so much that if any proposition be conjoined with it the result will be either an impossibility or strictly equivalent to the original. In a metaphysical mood Meredith once remarked that 'worlds' are the only real individuals; it is certainly true that his own interests have seldom taken in the ordinary calculus of names and predicates. (Prior 1962a, 9–10)

> I remember, too, C. A. Meredith remarking in 1956 that he thought the only genuine individuals were 'worlds', i.e. propositions expressing total world-states, as the opening of Wittgenstein's *Tractatus* ('The world is everything that is the case'). (Prior 2003c, 219)

This could illustrate what Meredith meant when he mentioned possible worlds, especially that he had in mind the view of the early (*Tractatus*) Wittgenstein. Nonetheless, does it imply that Meredith was committed to, or even seriously interested in possible worlds semantics? There are certain facts which might contradict this.

Prior's philosophical interpretation might not have been important for Meredith. This does not stand in contradiction to the fact that Meredith himself occasionally offered a philosophical remark, as reported by Prior. But such considerations may have been merely tentative and appear extraneous to where Meredith's real motivations and interests lay. This could be illustrated by the fact that Meredith never replied to Prior's philosophical objections to his system of logic. This by no means indicates that Meredith was indifferent to objections in general. On the contrary, in his correspondence with Prior Meredith was eager to respond to observations and queries regarding the formalism, and corrected mistakes if any appeared in his formal system.[13] But he did not discuss philosophical implications of his system nor the metaphysical queries Prior pointed out in the correspondence and in published works

[13] For instance, in his letter to Prior from 10th October 1956 [14], C. A. Meredith explained to Prior that he fixed objections of David Meredith regarding the problems with the rule of Modus Ponens in a certain system of logic.

as well. It could also be to some extent indicative that Meredith's possible ontological views are reported only by Prior, who was interested in ontological implications of his systems of logic, but not by Meredith the mathematician himself.

There is, however, a deeper difference between Meredith's system of modal logic and the joint work on the U-calculus. Meredith's system of modal logic was based on the many-valued matrix. The semantics for this system relies on truth-values only, even though certain truth-values are labelled as 'the world'. Though being titled as 'the world', 'n' and '$\dot{n}$' are quite distant from what is meant by this term in modern modal logic. There is also a small remark on Meredith's part in '*Modal Logic with Functorial Variables and Contingent Constant*' which could indicate that he favoured an approach to modal logic as a many-valued system of logic:

> I do not know if there are any philosophical applications of this system. I can only suggest that these philosophers who think that logic must be two-valued are confusing Hp and p.[14]. (Meredith and Prior 1965, 108)

While Prior's 'a' is a part of U-calculus as an intensional system of logic, Meredith's 'n' belongs to extensional systems of many-valued logic, in which it also played a role of a truth-value. This seems to open a considerable gap between Meredith and Prior. Meredith's contribution was, after all, not a contribution to (intensional) possible world semantics, hardly even a contribution to the very notion of possible worlds.

Finally, Prior was aware that there are also formal differences between the constant 'n' from Meredith's system of modal logic and the variable 'a' from U-calculus, even though both are entitled as 'possible worlds' in Prior's papers. In his paper '*Now*', Prior (2003b, 183 [38]) pointed out that 'n' cannot be replaced by 'a', since 'n' is a constant and 'a' a variable. Prior introduced an 'n' as a constant in his UT-calculus. In his interpretation 'n' is an instant-constant and also a propositional constant. It stood for a proposition which is true only in the moment of the utterance. For any utterance, that would obviously mean the "now'' in which it was uttered. It was a part of his calculus for 'now'. 'a', 'b' and 'c' were introduced as variables which stood for propositions similar to the

[14] 'Hp' is defined as '$\delta\Box(n\supset p)\supset\delta Hp$' by Meredith (Meredith and Prior 1965, 108 [20]).

proposition which was represented by 'n', i.e. true only in one current moment – Prior's famous instant propositions, which paved the way for hybrid logic (see Blackburn 2000 [1]) in the concomitant systems laid out as '*Four Grades of Tense-Logical Involvement*' (Prior 2003a [37]). This interpretation of Prior's without doubt bears some similarity to Meredith's 'n', but it does not cover the function it has in Meredith's system of modal logic and it is also used in a different type of calculus.

5 Conclusion

Although Meredith and Prior wrote several joint papers, this paper attempts to stress certain differences in their concepts of possible worlds including the variable 'a' and the constant 'n' which are associated with them (especially in Prior's various remarks, as we have seen). It is important to have these differences in a mind during the evaluation of Meredith's and Prior's work since the underestimation of the differences could – paradoxically - lead to an underestimation of both Meredith's and Prior's contribution to modern logic, as it emerges from the papers discussed.

When disregarding the philosophical queries, which Prior pointed out, Meredith's system of modal logic loses its weaknesses. If formal logic and a formally correct system were Meredith's essential interests, as indicated through his correspondence with Prior as well as the description found in the Necrology by his cousin and fellow logician David Meredith (D. Meredith 1977 [22]), then his system of modal logic fulfilled his goals. Prior could have objections to philosophical implications of the system, but they might have been unimportant to Meredith.

Due to the formulation of the paper '*Interpretations of Different Modal Logics in the "Property Calculus"*' Meredith and Prior were considered to be precursors of possible worlds semantics, as discovered and argued by (Copeland 2006 [3]). However, it was only Prior who needed this type of semantics for his intensional systems of modal and temporal logic. Although Prior benefited from Meredith's formal introduction (and Geach's sci-fi suggestions) in his U-calculus, the final semantics and the relation of accessibility were primarily his work. It might be more precise to say that it was just Prior, who was a precursor of possible world semantics. The Prior-Meredith's correspondence indicates that Meredith had no intentions to reserve a part of this honour to himself.

6 Appendix on *Computations and Speculations*

Prior's Nachlass is kept in a number of boxes (1–22, see http://www.priorstudies.org) in the Bodleian Libraries, Oxford – specifically, in the Weston Library, Special Collections.[15] In Box 8 is found an incomplete book manuscript with this frontpage:

Computations and Speculations

By

C.A. Meredith.

Edited by

A.N. Prior
Professor of Philosophy, University of Manchester.

Many, though not all observations on Meredith's 'n' are based indirectly, or sometimes directly, on this manuscript. The manuscript is typed, but incomplete. It originally consists of over 207 pages – cf. its Table of Contents, whose last section VIII.1. starts at p. 207. The manuscript as found in Prior's Papers Box 8 is somewhat complicated to overview. This is described in greater detail at (Hasle and Øhrstrøm 2014 [4]) http://www.priorstudies.org (Box 8, First Folder, Info). It should be noted that the manuscript is enclosed in a folder designated 'Miss P. Horne', who was the secretary in the department of Philosophy at the University of Manchester during Prior's years there. She on several occasions typed manuscripts for Prior.

According to a handwritten note by Mary Prior, found at the beginning of the folder, the manuscript was at one time submitted to OUP but was not accepted. According to a further note by Mary Prior, the missing parts formed the basis of five other publications, namely

1. C.A. Meredith & A.N. Prior. (1963). '*Notes on the axiomatics of the propositional calculus*', Notre Dame Journal of Formal Logic, vol. **4** (1963), pp. 171–187.

[15] Weston Library, Broad Street, Oxford, OX1 3BG
Enquiries: specialcollections.enquiries@bodleian.ox.ac.uk
Bookings: specialcollections.bookings@bodleian.ox.ac.uk

2. C.A. Meredith & A.N. Prior. /1964). '*Investigations Into Implicational S5*', Zeitschrift für mathematische Logik und Grundlagen der Mathematik, vol. **10** (1964), pp. 203–220.
3. C.A. Meredith & A.N. Prior. (1965). '*Modal logic with functorial variables and a contingent constant*', Notre Dame Journal of Formal Logic, vol. **6** (1965), pp. 99–109.
4. C.A. Meredith & A.N. Prior. (1968). '*Equational logic*', Notre Dame Journal of Formal Logic, vol. **9** (1968), pp. 212–226.
5. E.J. Lemmon, C.A. Meredith, D.Meredith, A.N. Prior, & I. Thomas. (1969). '*Calculi of pure strict implication*', Philosophical Logic, ed. by J.W. Davis, D.J. Hockney, & W.K. Wilson, D. Reidel, Dordrecht, 1969, pp. 215–250. (Previously published in mimeograph form, University of Canterbury, 1957.)

Dating

It is immediately obvious that the manuscript must have been produced during Prior's time as professor in Manchester, i.e., 1959–1965. Moreover the latest reference which can be found, in a footnote on p. 194, is from 1961 (namely, the second edition of Prior's *Formal Logic*). This makes it clear that the manuscript must have been produced in 1961 or later. Furthermore, since paper 1) above was published in 1963 this narrows down the possible dating to be 1963 at the very latest, and in all likelihood somewhat earlier. Finally it may be observed that even in *CaS* there is no clear identification of 'a' and possible worlds. Since in papers published in 1962 there is such an interpretation, *CaS* must have been produced by 1962 at the very latest, and in all likelihood somewhat earlier. In conclusion, we end up with a dating most likely 1962.

Authorship

As seen from the front page, C.A. Meredith is the author of the manuscript, and Prior figures as the editor. Nevertheless, it would appear that Prior did more than mere editing and indeed had an active hand in producing the running text. First of all, Meredith is mentioned in the third person throughout, e.g., *CaS* p. 111 and p. 112. This of course could have been a stylistic choice, even if somewhat unusual, but other passages seem to indicate quite strongly that Prior is the 'direct writer'. On page 138 we find this passage:

> Meredith first presented his work on D at a logical colloquium in Oxford in 1956; and it was there suggested at that colloquium by his cousin D. Meredith that there ought to be an axiomatization of that part of modal logic which employs no constant but strict implication. A number of us were provoked by his suggestion to begin work on this [which would later lead to the joint publication 1969f].[16] (*CaS* p. 138)

Moreover, in the five papers derived from *CaS*, Prior in all cases is presented not as editor but as the second author. David Meredith, cousin of C.A. Meredith and a fellow logician, stated this in his Necrology of C.A. Meredith:

> Many of the results that were prepared for publication by A. N. Prior in the sixties had been discovered as [CA] Meredith attempted to respond to queries from logical colleagues. (D. Meredith 1977, 514 [22]).

Here, 'published' certainly means more than simply accepting them for journal publication – Prior was not even on the editorial board of any of the journals in question. Overall, these features indicate that Prior had a more active role in the creation of *CaS* than merely editing, as otherwise suggested by the front page's 'Edited by A.N. Prior'. On the other hand, the original ideas, proofs etc. etc. without doubt stem from Meredith – completely or at least to a very high degree (it cannot entirely be ruled out that Prior could have amended a formula, a proof or a formulation here and there). Prior was a keen admirer of Meredith's work and hoped to motivate him to publish more, and his role in editing and working on this manuscript must be seen in that light. However, the cumulative evidence leads us to include *CaS* in our references with Prior as more than the editor, to wit, as second author.

Finally, it is worth mentioning that Section VI: 109–135 extensively deals with 'Meredith's n', which is alternately presented as a truth-value or a contingent constant which can be understood as a possible world.

[16] The colloquium mentioned was the logic colloquium organised by Prior et. al, cf. the *Logic Colloquium Programme: Oxford, 1956* in Prior's Papers in the Bodleian Library, Box 11, First Folder (see http://www.priorstudies.org – Boxes). This event was crucial to the development of significant logical work including Meredith and Prior's further cooperation. Several of the publications mentioned in this paper emanated, sooner or later, from this colloquium.

In a sense this has been an inspiration to Prior's later work on world propositions and instant propositions – important in its own right but even more important because this makes it belong to early part of the (pre)history of hybrid logic. Unfortunately, pages 123–135 are missing.

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The Significance of the Prior-Smart Correspondence for the Rise of Tense-Logic

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Abstract

The correspondence between Arthur Norman Prior and J.J.C. Smart was significant for Prior's development of tense-logic. Prior was influential in making Smart sceptical about Wittgenstein's view on pseudo-relations. Prior appears to have convinced Smart of the superiority of subsuming logical relations under the scope of operators. When Prior, however, disclosed the invention of tense-logic to Smart, it is clear from the correspondence that Smart did not find Prior's tensed operators convincing. Indeed, it turns out that Smart warned Prior against presenting tense-logic at the John Locke Lectures. Two questions are raised with regard to Smart's warning: Why did Smart warn Prior against presenting tense-logic at the John Locke Lectures, and why was Prior's tense-logic so well received? An argument is tentatively given based on the novelty of Prior's tense-logical operators to account for what Van Cleve (2016) [21] calls objectivity without objects.

Keywords: A.N. Prior, J.J.C Smart, Tense-logic, The Analytic School, Wittgenstein, Pseudo-relations

1 Philosophers Down Under

When A.N. Prior[1] met J.J.C. Smart, also known as 'Jack' Smart, in 1951 at a philosophical conference in Australia, it was the beginning of a lifelong friendship. Their friendship left behind a huge correspondence, which is kept in the Prior archive at the Bodleian Library in Oxford. We have 141 letters from Smart to Prior from the period of 26 September, 1951 to 29 August, 1969, just a few months before Prior died. Prior corresponded with many philosophers and logicians, but the Smart correspondence is by far the largest volume of letters in the Prior archive. It is also the only correspondence that lasted throughout Prior's professional career from before his invention of tense-logic until his death in 1969. Smart recalls that there were periods when letters were exchanged between them every week.[2] On 29 September, 1953, Smart sent two letters to Prior on the same day and began the second letter with an apology: "I fear I am bombarding you with letters" (Smart to Prior, 29 September 1953). The apology was definitely not needed since Prior was just as fond of the correspondence. Professionally as well as personally, the friendship was important for both; as both men lived down under, Smart in Adelaide, Australia and Prior in Christchurch, New Zealand, they were somewhat isolated from the greater analytical philosophical fellowship.[3]

The Prior archive unfortunately only holds three letters from Prior to Smart, and judging from the content of Smart's letters to Prior, finding more letters from Prior to Smart would be a great benefit for researchers. While much can be gained from having one side of the correspondence, our conclusions on discussions and content will necessarily be more tentative than if we were in possession of both sides. That said, the correspondence we have is valuable for Prior researchers and historians of analytic philosophy. Prior would typically send thoughts, ideas and drafts of future publications to Smart for his comments, and his responses help us date unpublished notes and trace development of ideas in Prior's authorship.

Smart's letters to Prior also provide a valuable treasure for research-

[1]This paper is based on research in the project "The Primacy of Tense: A.N. Prior Now and Then", funded 2016–2019 by the Danish Council for Independent Research – Humanities. DFF-FKK Grant-ID: DFF – 6107–00087.

[2]From personal correspondence with J.J.C. Smart, see (Jakobsen 2014 [4]).

[3]Ibid.

ers with regard to the development of Smart's philosophy and the influence of his friendship with A.N. Prior. The correspondence is deep, at times very frank, especially when the topic was on the philosophy of time but always saturated by a deep sense of mutual appreciation. In Prior, Smart had found a fellow analytic philosopher with whom he shared common central beliefs about the importance of logic for philosophy. He had found an astute thinker who would challenge his thinking. From the correspondence, we can see that Smart read through several drafts on Prior's John Locke Lectures on Time and Modality and gave valuable, and frank, criticism of Prior's view on time and tenses. Reading the correspondence makes it evident that it was a valuable source of inspiration for Prior and is part of the explanation for his frequent reference to Smart in *Time and Modality* (1957) [6] and *Past, Present and Future* (1967) [10]. The influence went both ways, however, and one of the greatest philosophical differences their correspondence had for Smart was the unravelling of Wittgenstein's philosophy.

2 Wittgenstein and the Analytic School

To understand Prior's role in undoing the influence of Wittgenstein on J.J.C. Smart, and his contribution to analytic philosophy in general, it is helpful to use Skorupski's distinction between *analytic philosophy* and what he calls the *Analytic School*. (Skorupski 2013 [16]). The nexus of the school is their view that logical analysis consists of two features. First, it is grounded in an analysis of language, and second, a proper analysis of language reveals traditional philosophical problems to merely be pseudo-problems. Second to Wittgenstein, Skorupski mentioned the importance of Carnap. In Carnap's words, the development of modern logic had made it possible to demonstrate that 'all the alleged statements in [the domain of metaphysics] are entirely meaningless' (Carnap 1932, p. 60, [1]). When Carnap wrote these words 1932, it is appropriate to describe his thoughts as belonging to an analytical research project oriented around, and originating from, the great achievement of modern logic, especially the work by Russell. The project was indeed sketched by Russell himself:

> Every philosophical problem when it is subjected to the necessary analysis and purification, is found to be not really

> philosophical at all, or else to be, in the sense in which we are using the world, logical. (Russell 1914, p. 42, [15])

Central to the project of the Analytic School is the removal of internal logical relations from the logical vocabulary itself. If all traditional philosophical problems, through logical analysis, are ultimately pseudo-problems, then there can be no room for a first philosophy of logic itself. It was essential for Russell's philosophy to separate on one side, pure logic as an entirely formal tool dealing only with atomic facts in atomic propositions, and on the other empirical science, such that logic in no way is a tool for discovery, but merely true in virtue of the form alone. However desirable and important the work is of revealing and dissolving pseudo-problems in philosophy, the radical nature of the project was, from the very outset, challenged by its own successful construction of a first-order logical language. The question remains: What accounts for facts deducible from logical constants that appears to constitute truth-relations internal to logic? If p is a fact, then so are $(p \vee q)$, $\sim\sim p$ and $(p \wedge \sim\sim p)$. If logical relations are not some subjective feature of the mind, a notion repugnant to the entire Analytic School, but an aspect of the external reality on a par with objective facts, then what accounts for such facts, and for our knowledge of them? Where a and b are facts and R some logical relation, then by virtue of what is the relation aRb, rather than bRa? The answer *that is just the way it is* will not do for the logical atomist, as then by discovering empirically that p is a fact, we can deduce, that $(p \vee q)$ is also a fact; this controverts the idea that science discovers facts and philosophy merely deals with formal languages. It would, of course, be a splendid answer for the logical realist, for whom the logician is guided by an *a priori* perception of the objective logical aspect of reality, in his discovery of axioms and truth-tables for logical constants. Such a reply was repugnant to the Analytic School. In Ramsey's words:

> I find it very unsatisfactory to be left with no explanation of formal logic: except that it is a collection of 'necessary facts'. The conclusion of a formal inference must, I feel, be in some sense contained in the premises and not something new; I cannot, believe that from one fact, e.g. that a thing is red, it should be possible to infer an infinite number of different facts, such as that it is not not-red, and that it is both red and not not-red. (Ramsey 1927, p. 161, [14])

This view of Ramsey's was quite in line with Wittgenstein's, from whom Ramsey, in his own words, had derived his view on logic, except his pragmatism, which he had derived from Russell (Ramsey 1927 [14]). A main aim of *Tractatus* is to provide a view on the fundamental aspects of logic that makes it possible to reject outright the need for any 'first philosophy' to account for the metaphysics of logic. The problem with internal logical relations was one of the primary problems Wittgenstein sought to provide an answer to in *Tractatus*. His answer was adopted by Smart and discussed with Prior in 1953.

3 The influence of Wittgenstein on Smart

According to Smart, Prior was instrumental in making him sceptical about Wittgenstein: 'He did a lot to make me skeptical of a lot of Wittgenstein's ideas' (Smart to Jakobsen, May 16 2011, in [4]). Smart's comment is interesting, since, even though Prior's authorship is based upon a philosophical realism, in opposition to the formalism espoused by Wittgenstein, his arguments against formalism was never explicitly directed at Wittgenstein. There are many reasons for this; the most important is likely the fact that the heyday of logical positivism was coming to an end, although philosophers such as Ayer still, in 1948, would defend central tenets of logical positivism against Popper's charge that it constituted an example of the very *a priori* philosophy that it sought to eliminate (see Popper et al., 1948, [5]). The idea that analysis would yield a universal language in which all philosophical problems could be seen to dissolve or be merely logical in Russell's sense of that word was dying. That being said, philosophical analysis was still for philosophers inspired by Wittgenstein, aimed at disclosing the 'philosophical nature' of the way propositions were used, dislocated from their ordinary usage, with the conclusion that the philosophical way was not the ordinary way and hence merely a pseudo problem. This approach to philosophy, of course inspired by the later Wittgenstein, is evident in Smart's early works: *The River of Time* (1949) [17], and *Descartes and the Wax* (1950) [18]. The former is one of his most influential papers. It contains a strong argument against the idea that time flows. It also argues that the illusion of time as a river is generated by what he describes as 'shifted syntax'. Shifted syntax is just the substantializing talk, or the hypostatization of meaning, and Smart's arguments involve an attempt

to saddle the A theorist with mythological reasoning.[4] Consider this quote:

> Substances exist in space; they are related to one another in a 3-dimensional order. Events are in time; they are related to one another in an order of earlier and later. Now if we think of events as changing, namely in respect of pastness, presentness, and futurity, we think of them as substances changing in a certain way. But if we substantialise events, we must, to preserve some semblance of consistency, spatialise time. Earlier than 'becomes' lower down the stream. It is thus easy to see how there arises the illusion of time as a river down which events float. ... Shifted syntax is an interesting linguistic phenomenon, and is at the root of most philosophical mythology. Indeed it might be useful to use 'philosophical mythology' just so as to indicate this sort of mythology. (Smart, 1949, [17])

Smart's move to reduce the substance talk of time to relation talk is partly driven by the impetus of the Analytic School with its animosity towards internal logical relations. The argument carries weight if the A theorist would recognise a need to fall in line with the party politics of the then prevailing Analytic School. It is of course anachronistic to count this against Smart's view in *The River of Time*, but it is only so for the very reason that the rigid tense-logic, to be developed by Prior five years later, was not yet invented. Absent a rigid language for a substance view of time, Smart has some justification in rendering talk about time better analysed with the tenseless rigorous relational perspective of Russell's logic.

4 Smart and Prior's discussion of Wittgenstein

The first time Smart and Prior discussed the philosophy of Wittgenstein was because of a point raised in a letter from Smart to Prior on 13 October, 1953. He described Wittgenstein as a 'Newton on philosophy' and brought up Wittgenstein's view on pseudo-relations. Smart asked

[4] For brevity's sake I will use A theorist and B theorist for philosophers who adhere to the dynamic view of time (A theorist) and those who hold to an eternalist view on time (B theorist).

rhetorically, 'Why do I call these pseudo-relations?" (Smart to Prior 13 October, 1953, [19]), and then proceeded to answer with a reference to *Tractatus* 5.461:

> Why do I call them pseudo-relations? Note that they need brackets. See Tractatus 5.461. And, more important, 'p' and 'q' do not enter into 'p $\vee$ q', 'p . q' etc. (when we assert 'p or q' we do not assert 'p' nor do we assert 'q'. ... '$\vee$' is not the name of a relation between 'p' and 'q' but of an operation we perform on 'p' and 'q' to form an entirely new proof. (Smart to Prior 13 October, 1953[19])

It is obvious that Smart accepted Wittgenstein's view on pseudo-relations, from *Tractatus* 5.461:

> Though it seems unimportant, it is in fact significant that the pseudo-relations of logic, such as $\vee$ and $\supset$, need brackets – unlike real relations. Indeed, the use of brackets with these apparently primitive signs is itself an indication that they are not the real primitive signs. And surely no one is going to believe that brackets have an independent meaning.
>
> (Wittgenstein Tractatus 5.461 [22])

Wittgenstein's point is central to the views of the Analytic School concerning the ultimate goal of a language in which all kinds of substance talk, even those involving relations, are explicated to relations that are external. Wittgenstein informed us that 'Instead of, the complex sign "aRb", says "a stands to b in the relation R", we ought to put, "*That* "a" stands to "b" in a certain relation says that aRb' (Tractatus 3.1432 [22]). He thus, by omitting R, suggested that there are no genuine logical relations at all. Based on this, it is obvious that disjunction and implication are merely pseudo-relations. Hence a solution is provided to internal logical relations. Facts like 'a' and 'b' are *Tractarian* particulars standing in some relation for which there is no sign, on the basis of which we can deduce other facts. Whatever might follow from logical relations only says something about language itself, not about particular facts.

On 22 October, 1953, a week later, Smart again wrote to Prior about Wittgenstein. It is now clear that Prior's response to the earlier letter (8 October, 1953) must have answered some of Smart's considerations

concerning pseudo-relations. Prior has clearly not accepted Wittgenstein's view and seems to have had success with persuading Smart to change his view:

> I rather like your idea of subsuming relation expressions under operation expressions. Your methods of talk which aren't the Fido-Fido fallacy are excellent: you get the same thing in Frege. ... And also Geach ... But I think you put it more clearly than either Frege or Geach. As you say '... is a parent of ...' isn't a name. But you can name the relation of parenthood by saying 'The relation of parenthood'. Similarly '$\vee$' doesn't name the relation of disjunction though the words 'the relation of disjunction' do. I think what you say on all this is sound and illuminating. It is worth developing.
>
> (Smart to Prior 22. October 1953 [19])

We are not in possession, as mentioned above, of Prior's letter, but from Smart's words it would appear that Prior has argued for approaching formal logic from an operator approach. This approach is central to Prior's formalism and is connected to his philosophical realism. Thus, in introducing truth-functions in *Formal Logic* (1955, p. 4, [8]), he does so on the basis of an operator approach for which he gives two examples: first the intensional operator:

1) 'I believe that ...'

And then an extensional operator:

2) 'It is not the case that ...'

For Prior, 1) as well as 2) are examples of well-formulated operators by means of which 'we construct one proposition out of another proposition', even though only 2 is truth-functional (Prior, 1955, p. 4, [8]). Smart's reply also reveals that Prior seems to have directly addressed the assumed formalism of Wittgenstein towards logical relations and argued for a distinction between the *use* of logical grammar, like disjunction and the naming of the same. This is of course a flat-out dismissal of the very foundation of Wittgenstein's approach to formal logic. The comparison with parenthood is typical of Prior's dismissal of formalism. Logic is about reality, and thus while it is obvious that '... is

a parent of ...' isn't a name, it is equally obvious that this is not a sufficient reason to deny that 'the relation of parenthood' does not name a genuine relation. What Prior seems to have done, with success, is to turn the table on Wittgenstein's formalism: If formalism requires us to postulate that disjunction cannot be a nameable relation, then so much the worse for formalism!

Finally, Prior might have written something about Polish notation with regard to Wittgenstein's comment on the use of brackets. Wittgenstein's view on the logical role brackets have is quite confused. Brackets are logical signs, merely present for formal reasons, and nothing of ontological importance follows from their presence or absence. Prior, in his response to Smart, could have pointed out that in Polish notation, brackets are not necessary for disjunction at all. Prior was at that time working on *Formal Logic* (1955) [8], written almost entirely in Polish notation, and many letters between Smart and Prior contain Polish notation from Smart, which would seem to indicate that he recognised its validity. Since Polish notation can provide a formalism without the need for brackets, the use of brackets is no proof that we, for logical reasons, must embrace formalism concerning logical relations like negation and disjunction.

Wittgenstein's formalism was diametrically opposite to the view Prior later expressed in terms of his view on logical relations. For Prior logic is about the real world, as he wrote in the unpublished note *A Statement of Temporal Realism*:

> Philosophy, including Logic, is not primarily about language, but about the real world. For example, the very simple logical truth that if John is sick then John is sick is not a truth about the sentence, 'John is sick' but a truth about John. It is not, of course, peculiar to John that if he is sick he is sick; it is true of everyone that if he is sick he is sick. Still it is true of John, and that is what the sentence says. Formalism, i.e. the theory that Logic is just about symbols and not about things, is false. Nevertheless, it is important to 'formalise' as much as we can, i.e. to state truths about things in a rigorous language with a known and explicit structure. It is also important to pay attention to the structure of our language in order to expose and eliminate philosophical 'pseudo-problems', and in order to distinguish real objects from mere 'logical

constructions'. (Prior 2014 [12])

Prior wrote these words against formalism after the publication of *Past, Present and Future* in 1967, and they are central to his entire development of tense-logic. There can be little doubt that whatever Prior responded to Smart in October would have been to the same effect.

5 Tense-logic and time

Smart's appreciation in 1953 of Prior's operator approach to logical relation would be challenged with Prior's invention of tense-logic in 1954. Tense-logic takes tensed verbs to be operators, on the basis of which propositions about time are constructed. The idea was, as is also evident from Smart's letter, not new to Prior, but it would be given a prominent role with tense-logic. The strength of Smart's argument in 1949 depended on the fact that the tense-logic was not yet invented by Prior. The historically interesting fact is that Smart and Prior's friendship began in 1951, and Prior could have wished for no better critic when he began to write to Smart about tense-logic in 1954. When he did, Smart pointed out that Quine was on his side and had recently written about it. There can be little doubt that the towering figure of Quine was to be reckoned with, and Smart's words illuminates vividly what Cresswell[5] has noticed, that the reason why modal logic could grow strong in New Zealand was due to its remoteness from Quine in USA.

> I don't believe in any metaphysical difference between past and future – in fact I believe the assertion of such a difference can be refuted. And here I have Quine on my side – cf. his article on Strawson in Mind. (Smart to Prior, 30 July 1954)

Smart's reference is historically rather interesting. Prior was at that time working on *Syntax of Time Distinctions* (1958) [7], which contains a critical comment on Quine and Strawson, on the basis of Quine's paper from

[5] "I think that one reason why the book was successful was that we were working in New Zealand and were away from the influence of Quine. Quine taught everybody that modal logic was a no-no, but we were too far away to know that. There's something to be said for working in a small country." (Cresswell 2008 [3]). The quote is from a video recording of a lecture available on YouTube. The quotation has been approved by Cresswell in personal correspondence.

1953, *Mr. Strawson on Logical Theory* [20]. In 1953, Quine had argued that taking modern logic seriously required tenseless quantification:

> The only tenable attitude toward quantifiers and other notations of modern logic is to construe them always, in all contexts, as timeless. ... Earlier I suggested that Mr. Strawson's failure to appreciate the tenselessness of quantification over temporal entities might be a factor in his underestimation of the scope of modern logic. I should like to go further and say that I do not see how, failing to appreciate the tenselessness of quantification over temporal entities, one could reasonably take modern logic very seriously.
>
> (Quine 1953, p. 443, [20])

Syntax of Time Distinctions [7] is one of the earliest publications by Prior on tense-logic. Although it was published in 1958, thus after Time and Modality (1957), it was written as the presidential address for the New Zealand Congress of Philosophy in 1954. It is highly likely that Prior's inclusion of Quine and Strawson is due to Smart's letter 30 July 1954. The article contains a defence against Quine's argument and reveals that Prior's introduction of tense-logic came with the force of medieval and ancient logicians.

> Modern exact logicians commonly operate with 'propositions' in the second (timelessly true) sense, while ancient and medieval logicians had in mind 'propositions' of the first ('tensed') sort. It should be emphasised, however, that there are no grounds of a purely logical character for the current preference, and that 'propositions' in the ancient and medieval sense lend themselves as readily to the application of contemporary logical techniques and procedures as do 'propositions' in the modern sense. (At this point Strawson, who regards it as a limitation of modern methods that they cannot cope with 'propositions' in the ancient and medieval sense, and Quine, who objects to the use of such 'propositions' in logic because modern methods cannot handle them, would seem to be equally in error.) (Prior 1958, p. 105, [7])

Prior's introduction of tense operators, on a par with truth-functional operators, as propositions from which we construct other propositions

is based on the very same operator approach which Smart found convincing as a response to Wittgenstein's talk of pseudo-relation. For Prior, if modern logic was incapable of taking tensed propositions seriously, then so much the worse of modern logic! The correspondence between Prior and Smart is historically very enlightening, since the topic of their correspondence in 1954 on tense-logic, would emerge in Prior's work subsequent to the publication of *Time and Modality* in 1957. The discourse would be about taking tenses seriously, and we now have a rather good idea about where that oft-used phrase originated. It come from Prior's Syntax of Time Distinctions, as a response to Quine. Thus later, in the same *Syntax of Time Distinctions*, Prior wrote:

> Time, one might say, figures in the l-calculus not as it does in medieval logic, which, as we have pointed out earlier, took tenses far more seriously than our own common logic does.
> (Prior 1958, p. 117 [7])

In 1954, Prior provided the logic to counter Smart's argument in *The River of Time*: A rigid-tensed logic to account for what Smart described as a substantialised talk about changes in time. Prior did so unapologetically and turned the table on the argument that substantialised talk is philosophical mythology. What Smart found illuminating and worth developing in Prior's approach to Wittgenstein began in 1954 to develop in a direction not foreseen, and clearly not to the logical taste of Smart. The operator approach to logical relations that Smart found interesting, despite its rejection of Wittgenstein's formalism, is the core of tense-logic. Treating 'it will be the case that ...' as a propositional function, generating other propositions is tantamount to taking tenses seriously in modern logic on a par with disjunction, implication and negation. Thus formally

Fp means 'it will be the case that p'

And

Pp means 'it has been the case that p'

From which two strong duals Hp as $\sim P\sim p$, and Gp as $\sim F\sim p$ can be defined, where

Hp means 'it has always been the case that p'

And

Gp means 'it will always be the case that p'

Tense-logic openly invites metaphysics back into logic to help us settle the rules for the internal relations of time. Should $p \supset PFp$ always be a thesis, for instance? Well, it depends on your overall metaphysical convictions concerning the past. If the past is necessary, such that $Pp \supset \Box Pp$, then $p \supset PFp$ will entail $\Box PFp$, and if p is substituted for Fp, then by the modal axiom $\Box(p \supset q) \supset (\Box p \supset \Box q)$ you can deduce $\Box Fp$. This is, of course, the traditional master-argument that Prior would discuss from 1954 to the publication of *Past, Present and Future* in 1967. The analysis grew and was ultimately framed in the semantics of branching time introduced by Kripke to Prior in 1958 (see Ploug & Øhrstrøm, 2012 [14]). The New Zealand Philosophical Congress was held at the end of August in 1954; as the conference approached, two more letters were written by Smart to Prior on 9 August. Smart brought up what still today are standard arguments against tense-logic, and he also commented on Prior's use of tense-logic with regard to an analysis of the Diodorus master-argument:

> Dear Arthur. Thanks for the 'Diodorus' and the comments in the letter. As far as metaphysics is concerned I do prefer the l-calculus. You tend to get philosophically misleading ideas (though in a sense perfectly OK ones) when you interpret the PF calculus. But of course no calculus will enshrine the use of the word 'now' because referring rules - semantic, not syntactic - are an essential part of its use. (Similarly no calculus can completely enshrine the rules for 'past' and 'future'.) We can translate all sentences using 'past' and 'future' into sentences using 'earlier than this utterance' and 'later than this utterance' and the words 'this utterance' are less philosophically misleading than 'now' simply because the word 'this' so clearly points outside language (or calculi). (Smart to Prior, 9 August, 1954)

What Smart referred to as the *l*-calculus is the title given by Prior to the tenseless earlier-later calculus which modern logic, at that time, favoured.

Smart's river of time argument was, as pointed out before, based on dismissing the superiority of what Prior now labelled the l-calculus. Prior would work on supplying reasons to many of the objections raised by Smart in the 9 August letter in 1954, throughout his authorship. In *Tense Logic and the Logic of Earlier and Later* (2003) [11], Prior can be said to answer Smart's challenge to 'enshrine the use of the word 'now' (Smart to Prior, 9 August, 1954). He would throughout his authorship hanker after supplying answers in syntax, rather than semantics, although he would eventually adopt the superior semantics of branching time for the discussion of determinism and future contingency. Prior was convinced that the Past, Future calculus (PF calculus) should not be interpreted in the l-calculus of *earlier and later*; it was rather the other way around:

> If there is to be any 'interpretation' of our calculi in the metaphysical sense, it will probably need to be the other way round; that is, the 1-calculus should be exhibited as a logical construction out of the PF calculus rather than vice versa. (Prior 1958, p. 116 [7])

In *Syntax of Time Distinctions,* this was still a matter 'yet to be investigated', which it would be for the next 13 years until the publication of *Past, Present and Future* (1967) [10]. In 1954 Prior, no doubt in response to Smart's 9 August letter, took the first step on a journey that essentially was about taking tenses seriously without ontological commitment to the times ranged over by tensed operators.

6 The l-calculus

The l-calculus gets its name from its 'distinctive operator' l for 'later', which is taken as basic, but it could have been 'earlier-than' relation as well, of course. Prior suggested that the first step towards translating the l-calculus in terms of the PF calculus is to point out that 'The date of p's occurrence is later than the date of q's occurrence' seems to be equivalent to 'It either is or has been or will be the case that it both is the case that p and is not but has been the case that q' (Prior, 1958, p. 116 [7]). In tense-logic, this would translate into:

$$(p\wedge\sim q\wedge Pq) \vee P(p\wedge\sim q\wedge Pq) \vee F(p\wedge\sim q\wedge Pq).$$

While we do not have Prior's reply to Smart's comment it is highly likely that the above first approximation would have been discussed at the New Zealand Philosophical Congress on 27 August. Perhaps Prior also wrote this in his reply to Smart's 9 August letter? This is, of course, speculating, but we know that he must have attempted some answer to Smart's criticism, but without success. Smart, rather frankly, replied on 13 August:

> I find your stuff on time very unconvincing. You beg the question. (Smart to Prior, 13 August, 1954)

We can be quite sure, that the two Australasian philosophers who have written most extensively in the middle of the 20^{th} century on the philosophy of time would fill the philosophical conference in New Zealand with an intense and stimulating discussion. For Prior, the question could be boiled down to the validity in treating 'it will be the case that ...' as well-formed a propositional function as 'either ... or ...' For Smart the difficulty was to maintain that such an approach was not taking modern logic seriously. Having granted that such an approach was formally acceptable for the latter, and thus accepted a rejection of Wittgenstein's formalism toward pseudo-relations, how could he now maintain that the former was formally wrong?

7 Smart's Warning

The news quickly spread of Prior's achievements and work, but the events that were to bring him, and tense-logic, into the centre of attention were the John Locke Lectures he gave on what subsequently was published as *Time and Modality* (1957) [6]. The first mention of the John Locke Lectures is in the correspondence between Smart and Prior, in a letter from Smart to Prior on 28 February, 1955, where Smart congratulated Prior on the John Locke Lectureship, calling it a 'very good news (though not all that surprising)'. Smart continued:

> You will do them a lot good, and no doubt shake some of them out of complacency, besides teaching them some formal logic. (Smart to Prior, 28 February 1955)

For the next few months, there is no mention of the upcoming lectureship. Ten letters later, on 16 May, 1955 it seems evident that Prior must

have written more extensively about what he would make the topic of the lectures or sent a draft to Smart. Smart was at least aware that, what he describes as 'time stuff' would be the topic of the lectures, and he warned in no uncertain terms against it:

> With due respect for your superior judgement. I wish you weren't lecturing on Time stuff for your John Locke lecturers. ... I really wish your John Locke lecturers were on Modal Logic, many valued systems, etc. including your stuff on Ł in J. Computational Systems ... With your time stuff you'll get involved in side issues, even straight philosophy, and not in the stuff that will do Oxford most good.
>
> (Smart to Prior, 16/5 1955, The Prior Collection, Box 3)

There is little doubt that these are the words of a friend. The warning would no doubt have been heeded by Prior, but it did not change much, as can be seen from Smart's response to 'a second set of TJL', sent 19 May, 1955. Smart once more warned Prior against the emphasis tense-logic gives to metaphysical and philosophical considerations:

> I still get the feeling that these lectures would more clearly represent your genius if you cut down on the metaphysics and stepped up the logic. As far as I can see you are at present trying to formulate ordinary tense logic, and as it translate.[6] This produces a pretty cumbersome system. That is, not a pretty system! (The tenseless logic is far superior aesthetically) ... I would, honestly, strongly suggest cutting down on the quasi-metaphysics and increase the amount of formal logic.
>
> (Smart to Prior, 19/6 1955, The Prior Collection, Box 3)

As it turned out, Oxford was more than ready for Prior's invention of tense-logic, and contrary to Smart's advice, it was not by virtue of minimising the amount of philosophy that the lectures became a success. Quite to the contrary, Prior's straightforward approach to philosophy in logic would help revitalise British Logic, as pointed out by Copeland:

> In the summerbreak following the John Locke Lectures Prior organized a logical colloquium in Oxford. In Britain in the

[6] Smart's handwriting is hard to decipher at this point.

> 1950s logic was deeply out of fashion and its practitioners were isolated and somewhat demoralized. ... Through his John Locke Lecturers, the colloquium, and his numerous visits around the country, Prior helped to revitalize British logic. (Copeland 1996, p. 6 [2])

Two questions must be answered in light of the correspondence between Smart and Prior. Smart was familiar with the strength of Prior's logical work and was initially convinced that Prior would teach them formal logic. That being so, why did he warn Prior against choosing tense-logic as his topic? Just as important is another question. Why was he wrong? Why did Prior's tense-logic receive such a warm welcome in Oxford, and in general in the philosophical logic? There is no easy single answer to the later question. We have one unpublished article at the archive at Oxford in which Prior's unique take on tenses and time is related to Wittgenstein, called *The Gramma and The Metaphysics of Time*, which appears to be an introduction and outline of a book that never got published. Prior's mention of Wittgenstein, in relation to Prior's take on time offers a clue to Prior's peculiar take on time. The article begins by addressing the view that 'different philosophical theories and systems are simply different languages in which men choose to describe the same world, rather than different views as to what the world is really like' (Prior, 2017 [13]) Prior then argued that reducing problems to linguistic decisions does not remove 'philosophical theories' if what these pertain to answers questions about the real world, and not just language. If questions like 'Is time circular, linear or branching' are about the world, and not just about language, and can be answered by tense-logic, then we have answers of a philosophical nature regarding the nature of time. So be it. Prior then turned to Wittgenstein:

> I call these formulations "crude" because they make use of the substantive "time", and we are thereby tempted, as Wittgenstein put it, to "seek" for a substance" for this substantive to denote. I want to reformulate them, if possible, in such a way that that substantive, and the temptation to which it gives rise, disappears. And I shall do this by attempting to represent each of the positions involved as a highly general proposition expressed by means of tensed sentences. (Prior 2017, p. 1)

The strength of tense-logic is its ability to make good sense of time from a natural language perspective, by quantifying over a domain of entities without ontic commitment over those entities. It gives the Wittgenstein-inspired tradition all it want: a way to deflate metaphysics and a logic modelled upon a natural language perspective. The cost is, however, metaphysical realism, which strikes at the very heart of the Analytic School. If the research project of the Analytic School should succeed, and philosophy be silenced for good, then logical analysis must yield a language with ontic commitment to entities with whom science can work, and the relations of the language are only pseudo relations. Prior's discovery of tense-logic provides a solution allowing for a very strong sense of philosophical realism without simply inflating the language, or as Van Cleve described it, to get objectivity without objects (Van Cleve 2016 [21]). Prior's analytical involvement with the metaphysics of time, qua the assumption of objectivity, does not leave the topic in the hands of psychology or linguistics and qua the assumption of presentism, it challenges the idea that it is 'hard' science that will enlighten us about the nature of time. His ability to maintain the logical high ground in this debate naturally called upon alternative explanations from philosophy.

8 Conclusion

Smart and Prior's correspondence appears to have led Smart to abandon his subscription to Wittgenstein's view on pseudo-relation. From the correspondence, it is clear that Smart found Prior's operator based approach to logical relations persuasive. It would however turn out that Prior's invention, which challenged Smart's view on time, was based on the same operator based approach, and basically challenged Quine's view that modern logic can only be taken seriously as tenseless. With the invention of tense-logic Prior demonstrated that modern logic can take tenses seriously. Prior's and Smart correspondence reveals the tension surrounding Prior's invention of tense-logic leading up to the John Locke lecturers where Smart several times warned Prior to not present tense-logic in Oxford. Smart, convinced that it would not show the logical acumen of Prior and only invite metaphysical problems, was however wrong. That Prior's presentation of tense-logic, contrary to Smart's expectations, turned out to be a success can tentatively be explained by Prior's ability to keep philosophical problems relevant for logic. The

metaphysics of time is what tensed-logic is objectively about, without a presupposition that we necessarily quantify over future or past objects.

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The Diodorean approach to time and modality from a historical and a philosophical perspective

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Abstract

Diodorus Cronus (ca. 340–280 B.C.) was an important philosopher and logician of the Megaric School. His principal contribution consists in a strong, logically oriented, characterisation of metaphysics, focused on the temporal aspects of important logical notions, in particular the understanding of conditionals and modality. Furthermore, he is well known for his so-called Master Argument which was designed to demonstrate that if something is possible then either it is the case already or it will be the case later. In this way Diodorus suggested a close connection between time and modality. According to Diodorus time can be seen as a series of temporal atoms. At any such atomic moment a proposition may be true or false.

Since we do not have the details of Diodorus' original argument, several scholars have tried to reconstruct the Master Argument as it might have been. In this paper, we consider two attempted reconstructions of the argument: one based on a certain interpretation of Diodorus' notion of implication, and one suggested by A.N. Prior and based on a tense-logical approach to time and reasoning. We argue that both reconstructions are possible from a historical point of view, but that the latter is more interesting than the former if the argument should be conceived as an argument

in favour of determinism.

Keywords: Master Argument, implication, discreteness, determinism, nominals.

1 Introduction

A.N. Prior (1914–69) as well as several other writers who have contributed to the rediscovery of temporal logic have referred to the works of Diodorus Cronus (ca. 340–280 B.C.).[1] In particular, they have discussed his Master Argument or *kyrieuon logos* (*κυριεύων λόγος*), which was designed to demonstrate that if something is possible then either it is the case already or it will be the case later. Since we do not have the details of Diodorus' original argument, several scholars have tried to reconstruct the Master Argument as it might have been.

In the following we shall discuss the Master Argument and its possible reconstruction. In section 2 we consider the main structure of the Master Argument in its historical context. Section 3 contains a discussion of the Diodorean notions of logic and time. In particular, we refer to a paradoxical account of motion (based on discreteness and linearity), and its consequences by interpreting the Master Argument premises. In section 4 we investigate the Diodorean idea of implication. Two reconstructions of the Master Argument will be considered in section 5. In the conclusion (6) we evaluate the two arguments presented in section 5 as possible reconstructions of the Master Argument and as arguments in favour of determinism. This will include reflections on the possible reactions to the two arguments and a suggestion to introduce *nominals* in the ancient context.

2 The main structure of the Master Argument in its historical context

It is not easy to reconstruct a biography of Diodorus Cronus. Indirect reports are not sufficient to decide definitively on the many obscure biographical points: most of them are posthumous and fragmentary,

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and sometimes the information concerning Diodorus is only implied. In some ways, we are forced to deal with guesswork and conjectures.[2] Quite a few surviving fragments help us place Diodorus Cronus as a member of the Megaric school.[3] Within this group Diodorus represents the dialectical tradition – i.e. the part of the circle with a strong interest in logic.[4]

Diodorus was born in Iasus, a city of Caria in Asia Minor, around the middle of the 4th century B.C. or perhaps a little later. However, there are no reports to date his birth. According to D.L. 2, 111, Diodorus' father was Aminia, his teacher was Apollonio Cronus, who was a pupil of Eubulides from Miletus.[5] Thus Diodorus may be chronologically collocated between Aristotle and the first Hellenism, as further testified by his leaving from Athens to Alexandria, suggesting that by that time, Athens might have begun to (slowly) lose its importance as an intellectual centre.[6] The Master Argument was supposed to make it possible to explain modalities in terms of time. According to one of the ancient

[2]Sedley offers a complete biography of Diodorus [32] – however, we do not fully agree with his account. He maintains that Diodorus was a rival of the Megarics. Following [32], there were two different schools, namely the Megaric and the Dialectic, and Diodorus was a member of the second. This view is supported by a passage in D.L. 2, 113. However Sedley's interpretation may be contested on the basis of other evidence, e.g., the *Megarika erōtēmata* (Μεγαρικὰ ἐρωτήματα) quoted in Plu. *Mor.* 13, 72, 1036e-f, as shown by [15, p. 297], and confirmed by the *sophismata* (σοφίσματα) of Stilpo, Diodorus, and Alexinus in Cic. *Luc.* 24, 75. Four years later than the publication of [32], Giannantoni published an interesting work on Diodorus [17], which completes the first reports collection of the Socraticorum Reliquiae [18].

[3]Diodorus' membership to the Megaric group is also documented by a neglected piece of evidence in Eust. *Ad Hom. Od.* 28, 46 – 29, 2, although it has been expressed some doubt [14].

[4]The word *dialectic* received different interpretations in Antiquity. For Plato, dialectic is the strategy of dividing a term into two further specifications. According to Aristotle dialectic is the syllogism whose premises are in general only probable. Stoics learnt dialectic from Megarics (in particular from Dialectics if that group really existed within the Megaric tradition). They identified dialectic and logic [1]. This was a flourishing new trend in logic, characterised by an interest in propositions rather than terms, in turn based on the attempt to find an objective criterion for entailment and validity and having also a strong focus on modalities.

[5]Eubulides is known as the author of the seven Megarics paradoxes (D.L. 2, 108). So we have here a further indication or perhaps explanation of the interest Diodorus took in logical matters.

[6]See, S.E. *P.H.* 2, 245, for the quotation by Erophilus, doctor from Alexandria; D.L. 2, 111 and S.E. *M.* 1, 309, for reports by the poet Callimachus from Alexandria about Diodorus.

commentaries the Diodorean position may be presented in the following way:

> [Aristotle] may possibly be talking also about the issue "What things are possible?", and about the so-called "Diodorean" answer, "What either is or will be". For Diodorus set down as possible only what either is or, in any event, will be. According to him, for me to be in Corinth was possible if I was in Corinth or if I was, in any event, going to be; if not, it was not even possible. And for the child to become literate was possible if he was, in any event, going to be. It is to establish this that Diodorus' Master Argument is posed (Alex.Aphr. *in APr.* 183, 34 – 184, 6; [19, p. 231]).[7]

The Master Argument was famous in Antiquity. There is no complete report on the inferential machinery connecting the premises by the proof of the principle that *nothing is possible which is neither true now nor ever will be*. The details of the argument are unknown: we only know its two premises and the conclusion. According to Epictetus, Diodorus argued that the following three propositions cannot all be true [21, p. 38]:

D1 Every proposition true about the past is necessary.
D2 An impossible proposition cannot follow from a possible one.[8]
D3 There is a proposition which is possible, but which neither is nor will be true.

Diodorus used this incompatibility combined with the plausibility of (D1) and (D2) to justify that (D3) is false (*Epict*. 2, 19, 1).[9]

[7] *Δύναται λέγειν καὶ περὶ τῶν Δυνατῶν, τοῦ τε, ὃ Διοδώρειον λέγεται, ὃ ἢ ἔστιν ἢ ἔσται· τὸ γὰρ ἢ ὂν ἢ ἐσόμενον πάντως δυνατὸν μόνον ἐκεῖνος ἐτίθετο. τὸ γὰρ ἐμὲ ἐν Κορίνθῳ γενέσθαι δυνατὸν κατ' αὐτόν, εἰ εἴην ἐν Κορίνθῳ, ἢ εἰ πάντως μέλλοιμι ἔσεσθαι· εἰ δὲ μὴ γενοίμην, οὐδὲ δυνατὸν ἦν· καὶ τὸ τὸ παιδίον γενέσθαι γραμματικὸν δυνατόν, εἰ πάντως ἔσοιτο. οὗ εἰς κατασκευὴν καὶ ὁ Κυριεύων ἠρώτηται λόγος* [ὁ] *ὑπὸ τοῦ Διοδώρου.*

[8] The alternative translation of D2 as "An impossible proposition cannot follow after a possible one" has been suggested. However, most scholars find this translation unlikely. See, [23, p. 16].

[9] "The Master argument appears to have been propounded on the strength of some such principles as the following. Since there is a general contradiction with one another between these three propositions, to wit: (1) Everything true as an event in the past is necessary, and (2) An impossible does not follow a possible, and (3) What is not true now and never will be, is nevertheless possible, Diodorus, realizing this contradiction,

But not everyone agree with Diodorus. Among the Stoics, it is known that two clever logicians, Cleanthes and Chrysippus, both accepted the soundness of the Diodorean argument; however, they suggest rather different reactions to it, since they embrace an opposed view in relation on determinsm and, unlike Diodorus, they fight it. Cleanthes and Chrysippus offer two strategies against the ancient Master Argument, respectively. In fact, Cleanthes and his group take D2 and D3 (and rule out D1); on the other hand, Chrysippus denies D2 and accepts D1 and D3. According to Epictetus' report, those two reactions against the Master Argument are presented as follows:

> One man will maintain, among the possible combinations of two at a time, the following, namely, (D3) *Something is possible, which is not true now and never will be*, and (D2) *An impossible does not follow a possible*; yet, he will not grant the third proposition (D1) *Everything true as an event in the past is necessary*, which is what Cleanthes and his group, whom Antipater has stoutly supported, seem to think. But others will maintain the other two propositions, (D3) *A thing is possible which is not true now and never will be*, and (D1) *Everything true as an event in the past is necessary*, and then will assert that, *An impossible does follow a possible.* But there is no way by which one can maintain all three of these propositions, because of their mutual contradiction (*Epict*. 2, 19, 2–5; [26, pp. 359–361]).[10]

In order to reconstruct the Master Argument we have to answer the following questions:

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used the plausibility of the first two propositions to establish the principle, Nothing is possible which is neither true now nor ever will be." ([26, p. 359]) – Ὁ *κυριεύων λόγος ἀπὸ τοιούτων τινῶν ἀφορμῶν ἠρωτῆσθαι φαίνεται· κοινῆς γὰρ οὔσης μάχης τοῖς τρισὶ τούτοις πρὸς ἄλληλα, τῷ* [τὸ] *πᾶν παρεληλυθὸς ἀληθὲς ἀναγκαῖον εἶναι καὶ τῷ* [ἀ]δυνατῷ *ἀδύνατον μὴ ἀκολουθεῖν καὶ τῷ δυνατὸν εἶναι ὃ οὔτ' ἔστιν ἀληθὲς οὔτ' ἔσται, συνιδὼν τὴν μάχην ταύτην ὁ Διόδωρος τῇ τῶν πρώτων δυεῖν πιθανότητι συνεχρήσατο πρὸς παράστασιν τοῦ μηδὲν εἶναι δυνατόν, ὃ οὔτ' ἔστιν ἀληθὲς οὔτ' ἔσται.*

[10] Λοιπὸν *ὁ μέν τις ταῦτα τηρήσει τῶν δυεῖν, ὅτι ἔστι τέ τι δυνατόν, ὃ οὔτ' ἔστιν ἀληθὲς οὔτ' ἔσται, καὶ δυνατῷ ἀδύνατον οὐκ ἀκολουθεῖ: οὐ πᾶν δὲ παρεληλυθὸς ἀληθὲς ἀναγκαῖόν ἐστιν, καθάπερ οἱ περὶ* Κλεάνθην *φέρεσθαι δοκοῦσιν, οἷς ἐπὶ πολὺ συνηγόρησεν* Ἀντίπατρος. *οἱ δὲ τἆλλα δύο, ὅτι δυνατόν τ' ἐστίν, ὃ οὔτ' ἔστιν ἀληθὲς οὔτ' ἔσται, καὶ πᾶν παρεληλυθὸς ἀληθὲς ἀναγκαῖόν ἐστιν, δυνατῷ δ' ἀδύνατον ἀκολουθεῖ. τὰ τρία δ' ἐκεῖνα τηρῆσαι ἀμήχανον διὰ τὸ κοινὴν εἶναι αὐτῶν μάχην.*

- What are the underlying ideas of logic (truth) and time?
- How should the Diodorean concept of "follow from" be understood?

3 The Diodorean notions of logic and time

Diodorus clearly assumes that some propositions are true *now* whereas others are not (i.e. they are false now). This was strongly stressed by Benson Mates in his famous book [21]. But how should his notion of "now" be understood? In order to answer this question we should consider his analysis of "motion".

According to S.E. *M.* 10, 119–120, Diodorus Cronus expressed his doctrine of motion in the following manner:

> If a thing moves, it moves now; if it moves now, it moves in the present time; and if it moves in the present time, it moves, therefore, in a indivisible time. For if the present time is divided, it will be certainly be divided into the past and the future, and thus it will no longer be present. And if a thing moves in an indivisible time, it passes through indivisible places. And if it passes through indivisible places, it does not move. For when it is in the first indivisible place it does not move; for it is still in the first indivisible place. And when it is in the second indivisible place, again it does not move but it has moved. Therefore nothing moves [11, p. 271].[11]

In this way, Diodorus refused movement as a process *in acto*, not *in se*. However, he endorses this stance because he recognises that what was seen in one place, now is seen in another place. In fact, Diodorus' real target is to highlight the paradox of motion, as an evolving process. According to him the present time is indivisible, and time as such is atomic.

[11] Εἰ *κινεῖταί τι, νῦν κινεῖται· εἰ νῦν κινεῖται, ἐν τῷ ἐνεστῶτι χρόνῳ κινεῖται· εἰ δὲ ἐν τῷ ἐνεστῶτι χρόνῳ κινεῖται, ἐν ἀμερεῖ χρόνῳ ἄρα κινεῖται. εἰ γὰρ μερίζεται ὁ ἐνεστὼς χρόνος, πάντως εἰς τὸν παρῳχημένον καὶ μέλλοντα μερισθήσεται, καὶ οὕτως οὐκέτ' ἔσται ἐνεστώς. εἰ δ' ἐν ἀμερεῖ χρόνῳ τι κινεῖται, ἀμερίστους τόπους διέρχεται. εἰ δὲ ἀμερίστους τόπους διέρχεται, οὐ κινεῖται. ὅτε γὰρ ἔστιν ἐν τῷ πρώτῳ ἀμερεῖ τόπῳ, οὐ κινεῖται· ἔτι γὰρ ἔστιν ἐν τῷ πρώτῳ ἀμερεῖ τόπῳ. ὅτε δὲ ἔστιν ἐν τῷ δευτέρῳ ἀμερεῖ τόπῳ, πάλιν οὐ κινεῖται, ἀλλὰ κεκίνηται. οὐκ ἄρα κινεῖταί τι.*

Diodorus tries to set up new categories to frame a notion of movement as a *succession of static and discontinuous stages*. In a modern context we may represent this view of time as a discrete series of units i.e. a structure isomorphic with the integers (or perhaps even the natural numbers – if there is a first element).

In order to reconstruct Diodorus' account of time as a discrete sequence of atoms or quanta, we consider the concept of *amereia* (*ἀμέρεια*), and more in depth his perspective on the partless bodies, namely the *amerē sōma* (*ἀμερῆ σῶμα*). According to Stob. *Ecl.* 1, 10, 16a, Diodorus is dealing with:

> Partless bodies, said minimals, unlimited in number but delimited in magnitude.[12]

We will follow Sextus Empiricus and assume the Diodorean concept of *amereia*: the minimal partless bodies are isomorphic in relation to places, namely, their shape is fitting with the filled place, being perfectly contained into minimal partless places (S.E. *M.* 10, 86, 1–2).[13] But, if such isomorphic schema about matter and place is valid, what about times? Does this fit also for it?

Let us consider again the *now*, namely the *nyn* (*νῦν*), and focus on its indivisibility. Two different explanations are available for that property: e.g. the Aristotelian and the Diodorean. More in general, the *now* refers to a given moment that *is* (*was* or *will be*) a present time. In a certain sense, that given present might be in the past, or perhaps it is going to be in some future. The assigned denotation to the *now* conditions our interpretation of the present as minimal and indivisible unit of time: thus, in Aristotle, an upholder of infinite divisibility,[14] the now delimits time and it is not a part of it, while in Diodorus the now is a quantum of time and its own minimal part.[15] Here is a recapitulation on

[12] <Διόδωρος> *ἐπίκλην Κρόνος τὰ ἀμερῆ σώματα ἄπειρα, τὰ δ' αὐτὰ λεγόμενα καὶ ἐλάχιστα· ἄπειρα μὲν κατ' ἀριθμόν. ὡρισμένα δὲ κατὰ μέγεθος.*

[13] "For the indivisible body must be contained in an indivisible place." ([11, p. 253]) – *Τὸ γὰρ ἀμερὲς σῶμα ὀφείλει ἐν ἀμερεῖ τόπῳ περιέχεσθαι.*

[14] Aristotle refers to potential divisibility *ad infinitum* (Arist. *Ph.* 3, 6, 206a 14–17).

[15] Let us consider the accounts presented by Arist. *Ph.* 4, 11, 219a 10–13 (Aristotle) and by S.E. *M.* 10, 119 (Diodorus).

In *Ph.* 4, 11, 219a 10–13 the Aristotelian perspective is described as follows: "Since anything that moves moves from a 'here' to a 'there', and magnitude as such is *continuous* [i.e. *syneches* (*συνεχές*), not-interrupted physically, and then dense in a mathe-

the Diodorean perspective about *isomorphism*: any kind of atom (times, bodies, places) is both the immediately next in relation to its predecessor and the immediately previous in relation to its successor.

The Diodorean time series presents a further characterisation: *linearity*. Once we accounted for discreteness, we should complementary introduce linearity. In modern terms, linearity means that time does not branch. The joint perspective can be considered as related both to the *determinism* and, according to Boeth. *in Int*. 234, 22–26, to modal notions:

> Diodorus delimits the possible as that which either is or will be; the impossible as that which when it is false will not be true; the necessary as that which when it is true will not be false; the non-necessary as that which either now is or will be false [8, p. 176].[16]

Diodorus maintains that something which did not or does not occur has to be considered as something impossible to happen in that given

matical sense], movement is dependent on magnitude; for it is because magnitude is continuous that movement is so also, and because movement is continuous so is time (*Ἐπεὶ δὲ τὸ κινούμενον κινεῖται ἔκ τινος εἴς τι καὶ πᾶν μέγεθος συνεχές, ἀκολουθεῖ τῷ μεγέθει ἡ κίνησις· διὰ γὰρ τὸ τὸ μέγεθος εἶναι συνεχὲς καὶ ἡ κίνησίς ἐστιν συνεχής, διὰ δὲ τὴν κίνησιν ὁ χρόνος*)."

On the other hand, Diodorus' perspective is reported by Sextus Empiricus (S.E. *M.* 10, 119): "If a thing moves in an indivisible time, it passes through indivisible places. And if it passes through indivisible places, it does not move (*Εἰ κινεῖταί τι, νῦν κινεῖται· εἰ νῦν κινεῖται, ἐν τῷ ἐνεστῶτι χρόνῳ κινεῖται· εἰ δὲ ἐν τῷ ἐνεστῶτι χρόνῳ κινεῖται, ἐν ἀμερεῖ χρόνῳ ἄρα κινεῖται*)."

From these two passages, we infer a dense model of the notion of time in Aristotle opposed to a discrete model in Diodorus, respectively. Basically, from the continuity of magnitudes depends the density of their structure, thus, the structural schema of both times, places, and bodies, is dense, by isomorphism. On the contrary, Diodorus focuses on minimal corpuscula or quanta into minimal *loca* and, by isomorphism, it is possible to claim that times, matter, and places have the same discrete structure. As a consequence, Diodorus does not admit any progressive motion and, as a paradoxical result, he allows that nothing moves. In fact, for any given now, nothing moves as a progression; even if something has moved (we note a change of place for it), since it was in a given discrete place before and now it has moved in another place. Lastly, if we do not see any active progression in time – in relation to the body motion – then time is discrete too. Therefore, motion is as a jump because time follows discreteness too.

[16]Diodorus possibile esse determinat, quod aut est aut erit; inpossibile, quod cum falsum sit non erit verum; necessarium, quod cum verum sit non erit falsum; non necessarium, quod aut iam est aut erit falsum.

time-atom. What happens, cannot be differently from its occurrence: in a certain sense, Diodorus admits that there is no room for possibilities that are counterfactual. As well as the case of discreteness (against the Aritotelian density), we can interpret the Diodorean linearity about the time series. We assume that the discreteness of time should be seen as a common presupposition – both Diodorean and Philonian – in order to deal with temporal logic.

Let us consider Simplicius' report and start from the following question: is it possible that a piece of wood burns? For instance, this might be the case of a driftwood in the sea. If, according to Simp. *in Cat*. 196, 1–2, we define as possible that a piece of wood burns, even if it is in the sea, then, we are in the exact case of a counterfactual possibility: in fact, it may be the case that, for some branch of time, on the contrary, there exists a given instant at which the same piece of wood is burning (Philo's stance).[17] But, if events follow the metaphysical necessity of *being*, then it is not the case of counterfactual occurrences, worlds, or possibilities: following Diodorus, the passage of time consists in the elimination of the contingencies, giving definitive judgement to open question [13, p. 51]. Therefore, if anything is possible, it either occurs or will occur following a course of time discrete and linear.

Philo's and Diodorus' stances are summarized, again, by Simplicius' commentary:

> Those who on the one hand judge *to dynaton* (τὸ δυνατὸν) in the way the ancients did, in terms of any sort of aptitude, as Philo did, but on the other hand now find it problematic according to the view of Diodorus who judges *to dynaton* by the outcome (Simp. *in Cat.* 196, 19–22; [16, p. 53]).[18]

[17] Philo's answer. This was: "That which is predicated in accordance with the bare fitness of the subject, even if it is prevented from coming about by some necessary external factor." On this basis he said that it was possible for chaff in atomic dissolution to be burnt, and likewise chaff at the bottom of the sea, while it was there, even though the circumstances necessarily prevented it [19, p. 231] – *Ὁμοίως καὶ περὶ τοῦ κατὰ Φίλωνα· ἦν δὲ τοῦτο τὸ κατὰ ψιλὴν λεγόμενον τὴν ἐπιτηδειότητα τοῦ ὑποκειμένου, κἂν ὑπό τινος ἔξωθεν ἀναγκαίου ᾖ γενέσθαι κεκωλυμένον. οὕτως τὸ ἄχυρον τὸ ἐν τῇ ἀτόμῳ ἢ τὸ ἐν τῷ βυθῷ δυνατὸν ἔλεγε καυθῆναι ὃν ἐκεῖ, καίτοι κωλυόμενον ὑπὸ τῶν περιεχόντων αὐτὸ ἐξ ἀνάγκης* (Simp. *in Cat*. 196, 1–2).

[18] *οἱ κρίνοντες μὲν τὸ δυνατὸν κατὰ τὸν αὐτὸν τοῖς ἀρχαίοις τρόπον, κατὰ τὴν ὁποιανοῦν ἐπιτηδειότητα, ὥσπερ ὁ Φίλων, ἀποροῦντες δὲ πρὸς αὐτὸν νῦν κατὰ τὴν Διοδώρου ἔννοιαν † ταύτῃ τῇ ἐκβάσει τὸ δυνατὸν κρίνοντος.*

Diodorus apparently thought of propositions as though they contained time-variables. These propositions are true at certain times and false at other times. Given that the Diodorean propositions can vary in truth-value from time-atom to time-atom it seems obvious to represent them as functions of time. Thus, propositions are functions from time-atom into truth values – and conversely, such functions are propositions. For the function application of a proposition p to an atom t we write $T(t, p)$ (i.e. the truth-value of p at t).

The Diodorean reasoning clearly involves tenses. In a modern context this means that we have to make use of operator P and F, by which new propositional functions Pp and Fp may be formed from any propositional function p. Pp is true at a given time-atom if and only if p is true at an earlier atom (i.e. an atom of time which is past relative to the present time-atom). Similarly, Fp is true at a given atom if and only if p is true at a later (future) atom. Furthermore, it may be possible to define the dual operator H as $\neg P \neg$ and G as $\neg F \neg$ in a straight-forward manner. Finally, a modern formalisation of the Master Argument will have allow for an undefined necessity operator, $\Box$, along with its dual operator, $\Diamond$, defined as $\neg \Box \neg$. Using this formalism we may formulate the Diodorean premises in an obvious manner:

D1 $Pp \rightarrow \Box Pp$

(i.e. if it is true that p took place in the past, then it is now unpreventable that p took place it the past)

D2 $(p \Rightarrow_{Diod} q \wedge \Diamond p) \rightarrow \Diamond q$

(i.e. if q follows from p in the *Diodorean sense*, and p is possible, the q is also possible)

D3 $\neg r \wedge \neg Fr \wedge \Diamond r$, for some r

(i.e. there is some certain event – corresponding to r – which is possible now, but which is not neither true now nor in the future)

The open question is still how the Diodorean implication, $\Rightarrow_{Diod}$, should be understood. This problem will be discussed in the next section. Once the question of the interpretation of the Diodorean implication has been settled, the reconstruction of the Master Argument will consist in demonstrating that (D1–3) lead to a contradiction, by a *reductio* strategy.

4 The Diodorean concept of implication

> Even on a matter that is among the very elements taught by the dialecticians, the proper mode of judging the truth or falsehood of a hypothetical judgement like "if day has dawned, it is light", what a dispute goes on! Diodorus holds one view, Philo another, Chrysippus another (Cic. *Luc*. 47, 143; [30, p. 653]).[19]

The debate on conditionals is a key topic in the history of logic from the first Hellenistic age. Every dialectician took part in that dispute started with a famous diatribe between Diodorus and Philo, and involving other sharp logicians as well Chrysippus among the Stoà members:

> All the dialecticians in common say that a conditional is sound when its finisher follows from its leader. But on the question of when it follows, and how, they disagree with one another and lay out competing criteria of following (*akolouthein*) (S.E. *M.* 8, 112; [4, p. 112]).[20]

The search for a truth criterion for conditional sentences is also linked to the Diodorean Master Argument. In fact, Benson Mates observed that the word *akolouthein* (*ἀκολουθεῖν*) used by Epictetus in (D2), is the same word used by Diodorus; for "is a consequent of".[21] It is well-known that Diodorus studied the nature of implication very carefully (cf. [23, pp.

[19] In hoc ipso quod in elementis dialectici docent, quo modo iudicare oporteat verum falsumne sit si quid ita conexum est ut hoc, "si dies est, lucet", quanta contentio est! Aliter Diodoro, aliter Philoni, Chrysippo aliter placet.

[20] *Κοινῶς μὲν γάρ φασιν ἅπαντες οἱ διαλεκτικοὶ ὑγιὲς εἶναι συνημμένον, ὅταν ἀκολουθῇ τῷ ἐν αὐτῷ ἡγουμένῳ τὸ ἐν αὐτῷ λῆγον· περὶ δὲ τοῦ πότε ἀκολουθεῖ καὶ πῶς στασιάζουσι πρὸς ἀλλήλους καὶ μαχόμενα τῆς ἀκολουθίας ἐκτίθενται κριτήρια.*

[21] The Greek verb *akolouthein* has different meanings: "to occur subsequently in time", "to imply", and "to be in accordance with", are the most plausible. The range of these meanings is very wide. To take the verb *akolouthein* to mean "to follow in time/after" (e.g. [36], [31]), is out of place when it is used by a valuable dialectician as Diodorus. From a logical point of view the most accurate definition of it seems *akolouthein* as "to infer", "to entail", maybe in a Diodorean sense (cf., e.g. [21], [13, pp. 40–41]). On the other hand, it would be a mistake to underrate the third solution: "to be in accordance with", which hints to a kind of modal principle of non-contradiction in relation to the possibility (e.g. [3], [22]), i.e. if a proposition is possible, at the same time its impossibility is ruled out.

19-]). The famous debate between Diodorus and Philo of Megara precisely concerned the relation between time and implication. Their views on implication were described in the following way by Sextus Empiricus:

> Philo, for example, said that the conditional is true when it does not begin with a true proposition and finish with a false one, so that a conditional, according to him, is true in three ways and false in one way. [...] Diodorus, on the other hand, says that a conditional is true which neither was nor is *able to* begin with a true one and finish with a false one – which conflicts with Philo's position (S.E. *M.* 8, 113, 115; [4, p. 112]).[22]

According to [21, p. 45], "a conditional holds in the Diodorean sense if and only if it holds at all times in the Philonian sense" and the Philonian implication is simply the material implication. Benson Mates has demonstrated that his conclusion is a clear consequence of a number of passages from the sources. If so, it will be obvious to represent the Diodorean implication involved in (D2) in terms of modern temporal logic as:

D2-Mates $(p \Rightarrow_{Diod} q)$ if and only if $(\forall t)(T(t,p) \rightarrow T(t,q))$

This interpretation seems straight-forward. However, alternatively it might be possible to understand "follow from" in (D2) as involving an undefined modal necessity operator, $\Box$. This seems to be what Prior suggested in his reconstruction of the Master Argument, i.e.:

D2-Prior $(p \Rightarrow_{Diod} q)$ if and only if $\Box(p \rightarrow q)$

5 Two possible reconstructions of the Master Argument

In order to show that the combination of the premises (D1–3) leads to contradiction we may tentatively assume the premises along with one

[22] *ἶον ὁ μὲν Φίλων ἔλεγεν ἀληθὲς γίνεσθαι τὸ συνημμένον, ὅταν μὴ ἄρχηται ἀπ' ἀληθοῦς καὶ λήγῃ ἐπὶ ψεῦδος, ὥστε τριχῶς μὲν γίνεσθαι κατ' αὐτὸν ἀληθὲς συνημμένον, καθ' ἕνα δὲ τρόπον ψεῦδος.* [...] *Διόδωρος δὲ ἀληθὲς εἶναί φησι συνημμένον ὅπερ μήτε ἐνεδέχετο μήτε ἐνδέχεται ἀρχόμενον ἀπ' ἀληθοῦς λήγειν ἐπὶ ψεῦδος. ὅπερ μάχεται τῇ Φίλωνος θέσει.*

of the two interpretations of the Diodorean implication. Let us first consider the option formulated in (D2-Mates). By (D3) there is some r for which at the present time t_0 it holds that it is possible but neither true now nor in the future. We also construct the proposition function w, which is only true at the atom just before the present atom, t_{-1}. Clearly, we have:

1.1 $\neg r \wedge \neg Fr \wedge \Diamond r$ [From (D3)]
1.2 $\Diamond r$ [From (1.1)]
1.3 Pw [From the definition of w]
1.4 $\Box Pw$ [From (1.3) and (D1)]
1.5 $(\forall t)(T(t,r) \rightarrow T(t,\neg Pw))$

[The Mates interpretation of the Diodorean implication, $r \Rightarrow_{Diod} \neg Pw$, holds since $\neg Pw$ is true whenever r is true. In fact, if for any t, if $T(t,r)$ is true, then that t precedes t_0 and hence Pw must be false at t.]

1.6 $\Diamond \neg Pw$ [From (1.2), (1.5) and (D2)]
1.7 $\neg \Box Pw$ [From (1.6). This contradicts (1.4). *Q.e.d.*]

Another possible reconstruction of the Master Argument based on (D2-Prior) has been suggested by A.N. Prior (cf. [23]). In order to establish the argument Prior needs two additional premises:

D4 $(p \wedge Gp) \rightarrow PGp$
D5 $\Box(p \rightarrow HFp)$

However, it is obvious that both (D4) and (D5) are reasonable given a discrete and linear notion of time. Furthermore, as shown in [3] both premises have been defended in the works of Aristotle. Assuming (D1–5) Prior's reconstruction can be presented in the following manner:

2.1 $\neg r \wedge \neg Fr \wedge \Diamond r$ [From (D3)]
2.2 $\Diamond r$ [From (2.1)]
2.3 $\neg r \wedge G\neg r$ [From (2.1)]
2.4 $PG\neg r$ [From (2.3) and (D4)]
2.5 $\Box PG\neg r$ [2.5 From (2.4) and (D1)]
2.6 $\Box(r \rightarrow HFr)$ [From (D5)]
2.7 $\Diamond HFr$ [From (2.6), (2.2) and (D2)]
2.8 $\neg \Box PG\neg r$ [From (2.7). Contradicts (2.5). *Q.e.d.*]

6 Conclusion

As we have seen there is a strong historical case for the interpretation of the Master Argument of Diodorus Cronus within a context of an understanding of time as discrete and linear. Furthermore, there seems to be at least to obvious interpretations of the second premise of the the Master Argument, (D2). Finally, it has been pointed out that each of these possible interpretations of (D2) may give rise to a possible reconstruction of the Master Argument. We shall briefly comment on each of these possible reconstructions from a historical as well as from a philosophical point of view.

In a historical perspective the interpretation of the Diodorean implication as (D2-Mates) seems straight-forward. And from this point of view (1.1–7) appears to be a likely reconstruction. However, as an argument in favour of determinism this argument is not very strong. Given the Mates interpretation of the Diodorean implication it is evident that any contradiction will follow from a proposition that is never true in the actual world. In consequence, if there are possible but never true propositions (D2-Mates) would mean that even contradictions are possible. This is not acceptable. Clearly, the indeterminist could easily get rid of the argument by rejecting its version of (D2). It appears that this was the reaction of Chrysippus. In consequence, it is rather likely that Chrysippus understood the Diodorean Master Argument is a way that comes close to (1.1–7).

In the argument (2.1–8) the interpretation of the Diodorean implication as (D2-Prior) makes the understanding of "follows from" rather complicated. However, this argument is in fact a possible reconstruction historically speaking. Furthermore, as an argument in favour of determinism this argument is much more interesting than (1.1–7). As pointed out by Prior the indeterminist response can be a rejection of (D1) – at least in some cases, as for instance by Cleanthes – or a rejection of (D4–5). Prior has named the former response *Ockhamism* and the latter *Peirceanism*.[23] Prior was not the only interested in the Master

[23]Both of these approaches have been introduced by [28, pp. 157–161] and [29, 113–136]. Prior himself adopted the Peirceanism as covering his own philosophical tenets [23, p. 195], at least in a first period, but we can feel also his Ockhamism, for instance as a more appropriate view to avoid the determinism. The Ockhamism has been axiomatised in [10] and [34], studied in e.g. [9], [25], and [20], dealing with the so-called *thin red line*. On the other hand, the Peirceanism has been axiomatised in [35], and studied

Argument as an argument in favour of determinism. He also wanted to study the formalities of the Diodorean modality. He introduced the topic in [27], while his [29, pp. 20–31] included a chapter on the search for Diodorean modalities.

From a formal point of view many logicians will probably find (2.1–8) much more attractive than (1.1–7), since the former is clearly based on deductive reasoning, whereas the latter mainly rely on semantical considerations.

It should also be mentioned that the use of w in (1.1–7) is interesting since it may be seen as an introduction of a *nominal*. In fact, by definition, the proposition function w is only true at the atom just before the present atom. Therefore, w is aimed to act both as a name for the time it is true at and as a standard propositional variable for a Priorean sentence. Certainly, we need some further details to classify w as a nominal in the standard way (see, [5]; [6]; [7]). Let us suppose w be a *non-simple proposition* in the way of Sextus Empiricus' report,[24] namely v_1&v_2, and v_1 be exactly the nominal, while v_2 be a given sentence that is true when v_1 is true. For instance, consider w to be instanced by (v_1) *It is the storming of the Bastille* and (v_2) *A revolution is happening*. v_1 stands for a given propositional function which is only true at one time when v_2 is true, and false at all other times. In this case w is something whose meaning includes a nominal. Nevertheless, there were also some very appropriate ancient uses of what is now called 'nominal', and they are related to the Diodorean diatribe on determinism and tempo-modalities, as well (i) *the* notorious *birth of Fabius, under the Dogstar* (Cic. *Fat*. 6, 12; 7, 14), and (ii) *the sea battle tomorrow*, given that we have certain sea battle in mind (Arist. *Int*. 9, 19a 18 – 19b 4). [25]

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e.g. in [12], and [24].

[24] According to S.E. *M.* 8, 95, 'non-simple propositions are those that are, for example, double – those that are constituted from a proposition taken twice or from different propositions by means of a conjunction or conjunctions – such as "If it is day, it is day", "If it is day, it is light", "If it is night, it is dark", "It is day and it is light", "Either it is day or it is night" ([4, p. 108])' – *ὐχ ἁπλᾶ δὲ ἐτύγχανε τὰ οἷον διπλᾶ, καὶ ὅσα δ' ἐξ ἀξιώματος. δὶς λαμβανομένου ἢ ἐξ ἀξιωμάτων διαφερόντων συνέστηκε διὰ συνδέσμου τε ἢ συνδέσμων, οἷον "εἰ ἡμέρα ἔστιν <ἡμέρα ἔστιν>· εἰ ἡμέρα ἔστι, φῶς ἔστιν· εἰ νὺξ ἔστι, σκότος ἔστιν· καὶ [εἰ] ἡμέρα ἔστι καὶ φῶς ἔστιν· ἤτοι ἡμέρα ἔστιν ἢ νὺξ ἔστιν*".

[25] (i) "If Fabius has been born with the Dogstar rising, Fabius will not die at sea" (Cic. *Fat*. 6, 12; [33, p. 63]) may be rephrased as follows: P(*Fabius' birth* $\wedge$ the Dogstar is in the sky) $\rightarrow$ G(Fabius is not dying at sea). Formalising the *nominal* in (i) by f:

$$P(f \wedge \text{the Dogstar is in the sky}) \rightarrow G(\text{Fabius is not dying at sea}).$$

Abbreviations of ancient texts

Alex.Aphr. *in APr.*	=	Alexander Aphrodisiensis, *In Aristotelis Analyticorum Priorum*
Arist. *Int.*	=	Aristotle, *De Interpretatione*
Ph.	=	_____. *Physica*
Arr. *Epict.*	=	Arrianus, *Epicteti Dissertationes*
Boeth. *in Int.*	=	Boethius, *In Aristotelis De Interpretatione*
Cic. *Fam.*	=	Cicero, *Epistulae ad familiares*
Fat.	=	_____. *De Fato*
Luc.	=	_____. *Lucullus*
D.L.	=	Diogenes Laertius, *Vitae Philosophorum*
Eust. *Ad Hom. Od.*	=	Eustathius Thessalonicensis, *Commentarii ad Omeri Odysseam*
Plu. *Mor.*	=	Plutarch, *Moralia*
Simp. *in Cat.*	=	Simplicius, *In Aristotelis Categorias Commentarium*
S.E. *M.*	=	Sextus Empiricus, *Adversus Mathematicos*
P.H.	=	_____. *Pirroneion Hypotyposeon*
Stob. *Ecl.*	=	Stobaeus, *Eclogae*

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(ii) "To be or not to be a sea-battle tomorrow" (Arist. *Int.* 9, 19a; [2, p. 53]) may be also expressed as: ((A sea-battle occurs $\wedge$ *tomorrow*) $\vee$ (A sea-battle does not occur $\wedge$ *tomorrow*)). Formalising the *nominal* in (ii) by t:

$$((\text{A sea-battle occurs} \wedge t) \vee (\text{A sea-battle does not occur} \wedge t)).$$

As a consequence, we can expect that the recognition of *nominals* in ancient texts opens to renewed interpretations in the history of ancient logic.

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A Note on the Expressive Power of Temporal Discourse in Natural Language

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Abstract

In this note I examine the arguments of Cresswell (1990) and van Benthem (1977) in favor of the view that the expressive power of a natural language amounts to explicit quantification over times. Section 1 describes the structure of Cresswell's line of argument in his book *Entities and Indices*. In Sections 2–3, I discuss the key examples given by van Benthem and Cresswell to support the claim that intensional theorists need to posit infinite indices and infinite *index*/*then*-operators in order to capture the power of English temporal discourse. Section 4 is devoted to discussing a different kind of example due to Saarinen (1978). In section 5, I echo Yanovich's (2011, 2015) observation that Cresswell's proof in the fourth chapter of *Entities and Indices* does not show that a system with infinite indices and infinite *index*/*then*-operators is equivalent in power to a system with explicit quantification over times.

Keywords: J. van Benthem, M. J. Cresswell, expressive power, multiple indexing, *index*/*then*-operators, E. Saarinen.

1 Introduction

In his book *Entities and Indices* [5], M. J. Cresswell advocated the view that natural language is ontologically committed to possible worlds. In

order to substantiate this thesis, Cresswell argued that modal discourse in natural language requires a semantics whose power amounts to explicit quantification over worlds.[1] In the book Cresswell also drew a parallel between the modal case and the temporal case. He suggested that possible worlds are semantically on a par with times and argued that temporal discourse in natural language has the power of explicit quantification over times. Cresswell's analysis of modal and temporal expressibility was based on the prior work of a group of logicians who had studied the behavior of multiply-indexed operators such as the *now*-operator of Kamp and Prior, the *index/then*-operators of Vlach, and the modal counterparts of these operators.[2] One of the most influential contributions to this literature was a review by Johan van Benthem published in 1977. As Cresswell himself acknowledged, van Benthem's review anticipated the central conclusions of *Entities and Indices* regarding temporal expressibility.

Cresswell's discussion in *Entities and Indices* has been viewed by the critics of intensional semantics as a persuasive line of argument against the use of modal and temporal operators in natural language semantics.[3] In this note I will challenge the arguments provided by Cresswell and van Benthem to support the view that the expressive power of a natural language amounts to full quantification over times. Although there are interesting similarities between temporal expressibility and modal expressibility, I will focus my attention on the former.

The argument of Cresswell concerning temporal expressibility had two parts. First, he argued that an operator-based language can only reach the expressive power of English if it employs infinite *index/then*-operators and has a semantics with infinite temporal indices. Second, he gave a formal proof that an operator-based language of this sort is as powerful as a language of predicate logic with temporal variables. The upshot of the argument was that English temporal discourse has the power of full quantification over times.

The first part of Cresswell's argument took the form of a slippery-

[1] Cresswell assumed that a language is ontologically committed to a domain of entities if it requires a semantics that is equivalent in power to explicit quantification over those entities (see Cresswell 1990, pp. 1–2 and 61–62).

[2] See Kamp 1967 and 1971, Prior 1968, Åqvist 1973, Vlach 1973, Segerberg 1973, Crossley & Humberstone 1977, and van Benthem 1977.

[3] See e.g. Schlenker 2003, section 3, King 2003, section 4, Kratzer 2014, section 5, and Schaffer 2012, section 2.2.

slope reasoning. The first step of the slippery slope was to argue that the advocate of temporal operators needs to introduce *index*/*then*-operators sensitive to two moments of time in order to express the truth-conditions of the kind of sentences that motivated Kamp (1971) and Vlach's (1973) double-index systems of temporal logic. The second step was to show that the argument for double indexing generalizes: for any finite number of temporal indices posited by the intensional theorist, there is some English sentence that can only be expressed in an intensional language with a greater number of temporal indices and a greater stock of *index*/*then*-operators.

Let us turn to the concrete examples that allegedly support the second step of the slippery-slope reasoning. I will discuss these examples in sections 2–4. The second part of Cresswell's argument—the one that involves a formal proof—will be briefly discussed in Section 5.

2 Van Benthem on Multiple Indexing

In his 1977 review [2], van Benthem observed that some temporal logicians had proposed increasingly complex operator-based systems in order to capture the truth-conditions of certain kinds of sentences. One central thesis of van Benthem's review was that this tendency made such systems converge towards a logical system with explicit quantification over times. Van Benthem argued for this thesis in a section of the review devoted to Vlach's doctoral dissertation. Vlach had studied the logic of an intensional language equipped with the standard operators H and G, a *then*-operator R, and an *index*-operator K. This language was doubly indexed: its formulas were evaluated relative to two moments of time. Vlach (1973, pp. 1–3, [18]) argued that there are English sentences that can be symbolized in his formal language but that cannot be symbolized with the *now*-system of Prior and Kamp. According to van Benthem (1977, pp. 417–418, [2]), there are also sentences that cannot be expressed in Vlach's K/R-language, but are expressible in a triply-indexed variant of that language. Van Benthem suggested that this is the beginning of a slippery slope which ultimately leads to the postulation of infinite indices and infinite *index*/*then*-operators. Before examining his argument, let me characterize the *index*/*then*-operators of Vlach's language.

I will assume that $\boldsymbol{L}$ is a first-order language of temporal logic equip-

ped with the standard operators P, F, H, and G. I will also assume that $\boldsymbol{L}$'s vocabulary includes all the individual constants, predicates, and attitude operators which we may need in order to symbolize the English sentences considered in this note. I will use subscripts to name the languages that are obtained by adding more operators to $\boldsymbol{L}$. For example, $\boldsymbol{L}_{\mathbf{KR}}$ is the language that results from adding the operators K and R to the vocabulary of $\boldsymbol{L}$.

K and R are interpreted by giving their semantic clauses. Let us assume that the interpretation function of $\boldsymbol{L}_{\mathbf{KR}}$ is a function $[\![\ ]\!]^{g,w,t,t'}$ that assigns truth-values to the well-formed formulas of $\boldsymbol{L}_{\mathbf{KR}}$ relative to a variable assignment, a possible world, and two temporal indices.[4] Then, for any wff φ of $\boldsymbol{L}_{\mathbf{KR}}$, variable assignment g, world w, time t, and time t',

(K) $[\![\text{K } \varphi]\!]^{g,w,t,t'} = 1$ iff $[\![\varphi]\!]^{g,w,t,t} = 1$

(R) $[\![\text{R } \varphi]\!]^{g,w,t,t'} = 1$ iff $[\![\varphi]\!]^{g,w,t',t'} = 1$

We can view K as an operator that copies the time of evaluation—the first temporal index of $[\![\ ]\!]^{g,w,t,t'}$—and stores it in the second-temporal-index slot. At a later stage of a truth-condition computation, the operator R may retrieve the stored time by turning it into the time of evaluation of its embedded formula. R may thus be viewed as a retrieving operator.[5]

It is possible to add to $\boldsymbol{L}_{\mathbf{KR}}$ an *index*-operator K′ and a *then*-operator R′ that act upon a third temporal index. While K′ stores a given time of evaluation in the slot of the third temporal index, R′ retrieves the time stored in that slot and makes it the current time of evaluation. The interpretation function of the language $\boldsymbol{L}_{\mathbf{KRK'R'}}$ assigns truth-values to the well-formed formulas of $\boldsymbol{L}_{\mathbf{KRK'R'}}$ relative to a variable assignment, a world, and three temporal indices. The *index*/*then* operators of this language have the following semantic clauses:

For any wff φ of $\boldsymbol{L}_{\mathbf{KRK'R'}}$, variable assignment g, world w, and times t, t', and t'',

[4] Our temporal indices must be thought of as moments of time. For simplicity, I will also call them *times*. For a detailed characterization of the formal languages discussed in this note, see Rey 2016 [12], chapter 1.

[5] R and the *now*-operator N (Kamp 1971) have the same semantic clause. In a language with the two operators K and R, there are formulas in which an occurrence of R cannot be read as expressing the meaning of the English word *now*. In some of those formulas, R seems to behave like the word *then*. See Vlach 1973, pp. 1–9, 39–40.

(K)	$[\![\text{K } \varphi]\!]^{g,w,t,t',t''} = 1$	iff	$[\![\varphi]\!]^{g,w,t,t,t''} = 1$
(R)	$[\![\text{R } \varphi]\!]^{g,w,t,t',t''} = 1$	iff	$[\![\varphi]\!]^{g,w,t',t',t''} = 1$
(K′)	$[\![\text{K}' \varphi]\!]^{g,w,t,t',t''} = 1$	iff	$[\![\varphi]\!]^{g,w,t,t',t} = 1$
(R′)	$[\![\text{R}' \varphi]\!]^{g,w,t,t',t''} = 1$	iff	$[\![\varphi]\!]^{g,w,t'',t',t''} = 1$

In any language that is an extension of ***L***, the operators P, F, H, and G are interpreted in the usual way. They shift the current time of evaluation to a time located in its past or future. I will assume that the closed formulas of any extension of ***L*** are true or false with respect to a world and time of utterance. If φ is a closed wff of a doubly-indexed extension of ***L***, φ *is true* with respect to a world of utterance w_0 and time of utterance t_0 just in case $[\![\varphi]\!]^{g,w_0,t_0,t_0} = 1$, for any variable assignment g. Similarly, if ψ is a closed wff of a triply-indexed extension of ***L***, ψ *is true* with respect to a world of utterance w_0 and time of utterance t_0 just in case $[\![\psi]\!]^{g,w_0,t_0,t_0,t_0} = 1$, for any variable assignment g. The same sort of truth-definition can be given for other extensions of ***L***. For our purposes, the most relevant consequence of such truth-definitions is that the computation of the truth-condition of any closed formula starts at an index coordinate in which the value of every temporal-index slot is the time of utterance. If the semantics of the language has n temporal indices, there are n copies of the time of utterance available for retrieval at the beginning of the computation.

Let us now return to the argument of van Benthem about Vlach's formal language. Van Benthem (1977, pp. 417–418 [2]) claims that sentence (1) is not expressible in Vlach's K/R-language.

> (1) There will always jokes be told that were told at one time in the past

Needless to say, (1) is an odd sentence. Its most salient reading seems to be (2).

(In specifying truth-conditions, I will call w_0 and t_0 the world of utterance and time of utterance of the formulas that we are considering.)

> (2) For every time t such that $t_0 < t$, there is a time t' such that $t' < t_0$, and there is a joke d such that d is told in w_0 at t and d is told in w_0 at t'.

Informally, (2) says that for any future time t, there was a past time t' such that a joke that will be told at t was told at t'. But (2) is not the

reading of (1) in which van Benthem is interested. (2) is expressible in a double-index system with the operators K and R. It is expressed, for example, by formula (3) of $\boldsymbol{L}_{\mathbf{KR}}$—for simplicity, let us assume that the bound variable of (3) ranges over jokes.

(3) G $\exists x$ (**be told** $x \wedge$ R P **be told** x)

Van Benthem gives a formal specification of the (alleged) reading of (1) which he has in mind. He is interested in the reading where *at one time in the past* takes wide scope over *there will always jokes be told*. In formal terms:

> (4) There is a time t such that $t < t_0$ and for every time t' such that $t_0 < t'$, there is a joke d such that d is told in w_0 at t and d is told in w_0 at t'.

Roughly, (4) says that there was a past time t such that for any future time t', some joke that was told at t will be told at t'. (4) entails (2), but (4) can be false in a scenario in which (2) is true. It is controversial whether (1) has the reading specified in (4). Most English speakers have to make an effort to read (1) as expressing (4). Some English speakers report that they do not even get that reading.

Van Benthem does not prove that (4) cannot be expressed in the K/R-language. He considers and rejects a number of possible symbolizations of (4) in terms of the operators P, G, K, and R.

It is not difficult to find ways of expressing (4) if we switch to a triple-index framework. (5) is a wff of $\boldsymbol{L}_{\mathbf{KRK'R'}}$ that expresses (4).

(5) P K′ R G $\exists x$ (**be told** $x \wedge$ R′ **be told** x)

In brief, van Benthem's argument involving (1) seeks to show that (1) has a reading that is expressible in a triply-indexed language like $\boldsymbol{L}_{\mathbf{KRK'R'}}$ but not in a doubly-indexed language like $\boldsymbol{L}_{\mathbf{KR}}$.

In the appendix to his dissertation, Vlach had considered the possibility of constructing intensional systems with three or more temporal indices and appropriate *index*/*then*-operators that manipulate those indices. However, van Benthem dismisses the strategy of dealing with (1) and similar counterexamples by positing more temporal indices and more operators.

> In an appendix, Vlach mentions a safety valve which blocks this counterexample and similar ones. It consists in adding operators $[R_1]$, $[R_2]$, ... and corresponding K_1, K_2 ... in any quantity. This will take care of all cases of cross-reference, but [...] such a move degenerates into using a typographical variant of predicate logic (with subscripts instead of variables), merely without *calling* it predicate logic.
>
> (van Benthem 1977, p. 418 [2])

Here van Benthem is suggesting that a system with infinite temporal indices and infinite *index*/*then*-operators is simply a notational variant of a predicate-logic system with explicit quantification over times. I will briefly discuss this suggestion in section 5. For the moment, let us return to van Benthem's argument regarding (1).

As I explained before, van Benthem's assumption that truth-condition (4) is a reading of (1) is controversial and, moreover, van Benthem assumes without proof that (4) cannot be expressed in Vlach's K/R-language. Even if we grant him these two assumptions, his argument does not show that triple indexing is necessary in order to express (4) by means of temporal operators. There are doubly-indexed extensions of $\boldsymbol{L}$ that can express (4). One such extension is a language $\boldsymbol{L}_{\mathbf{RG}}{}^{+}$ that employs Vlach's *then*-operator R and a future operator G^+ which shifts the second temporal index. This is the semantic clause of G^+:

For any wff φ of $\boldsymbol{L}_{\mathbf{RG}}{}^{+}$, variable assignment g, world w, time t, and time t',

$$(G^+) \quad [\![G^+\ \varphi]\!]^{g,w,t,t'} = 1 \quad \text{iff} \quad \text{for every time } t'' \text{ such that } t' < t'', \\ [\![\varphi]\!]^{g,w,t,t''} = 1$$

With the aid of G^+, (4) can be symbolized as (6).

(6) P G^+ $\exists x$ (**be told** $x \wedge$ R **be told** x)

By writing down a standard truth-condition derivation, one can show that (4) is the truth-condition of (6). Since (4) is expressible in $\boldsymbol{L}_{\mathbf{RG}}{}^{+}$, it follows that triple indexing is not necessary to express (4). Thus, van Benthem's example (1) does not provide a good motivation for introducing triply-indexed operators.

Incidentally, note that a sentence like (7) seems to come closer to expressing (4) than (1) does.

(7) There was a time in the past such that it will always be the case that some joke that was told then will be told again

(4) seems to be a reading of (7). But it is important to stress that if (1) and (7) have a reading that corresponds to (4), this is so because of the role that the expressions *at one time in the past* and *there was a time in the past* play in these sentences. It does not seem possible to express (4) in English without using expressions which quantify explicitly over times. We will return to this point in the next section.

3 Cresswell on Temporal Discourse

Let us move now to Cresswell's discussion of multiple temporal indexing. Like van Benthem, Cresswell (1990, chapter 2 [5]) argues that the kind of considerations that motivate double temporal indexing ultimately lead to infinite temporal indexing. The key example that Cresswell uses to argue for this claim is sentence (8).

(8) There will be (two) times such that all persons now alive will be happy at the first or miserable at the second.

The reading of (8) in which Cresswell is interested is (9).

(9) There is a time t such that $t_0 < t$, there is a time t' such that $t_0 < t'$, and for every person d, if d is alive in w_0 at t_0, then d is happy in w_0 at t or d is miserable in w_0 at t'.

Note that formula (10) does not express (9)—I assume that the bound variable of (10) ranges over persons.

(10) $\forall x$ (**alive** $x \rightarrow$ (F **happy** $x \vee$ F **miserable** x))

In an operator-based formula that expresses (9), the operators which introduce the two future times should take wide scope over the universal quantifier. Additionally, the subformula **alive** ***x*** should be evaluated at the time of utterance. No formula of a doubly-indexed extension of ***L*** can meet these two conditions. If two future operators appear before the universal quantifier, it will be necessary to delete the future time

introduced by one of these operators in order to retain the time of utterance as one of the two temporal indices. In other words, (8) requires a semantics that can keep track of three different times.

As Cresswell correctly points out, the problem posed by (8) generalizes. For (8)'s disjunction can be indefinitely extended and each extended version of (8) introduces a new time which the semantics must retain. Consider (11).

> (11) There will be (three) times such that all persons now alive will be happy at the first, or miserable at the second, or sick at the third.

Sentence (11) poses a problem for triply-indexed languages analogous to the problem that (8) poses for doubly-indexed languages. Since we can generate more complex variants of (8) without limit, Cresswell concludes that we cannot put an upper bound on the number of times that have to be simultaneously considered in the evaluation of English sentences.

Is Cresswell's example (8) problematic for the sort of semantic project that Kamp and Vlach were pursuing in their seminal works on doubly-indexed operators? Cresswell is right in pointing out that if one wants to express the truth-conditions of (8) and its variants by relying only on *index/then*-operators, then one has to posit infinite temporal indices. But, arguably, Kamp and Vlach did not want to analyze (8) and its variants this way. At the beginning of the appendix to his dissertation, Vlach said quite clearly that a sentence like (8) was not a target of his K/R-system.

> There are other ways of doing the sort of thing that the system of this paper is supposed to do and many systems that are stronger than the present one. The present system was chosen for its relative simplicity, and because it seems sufficient to handle most actual English examples that would naturally be expressed without the use of expressions that refer explicitly to times, like 'the first moment'.
>
> (Vlach 1973, p. 418 [18])

Here Vlach is excluding (8) and its variants from the range of application of his K/R-system. He did not think that such sentences were problematic for his general approach. Although he described a hierarchy of

multiply-indexed systems which are stronger than the K/R-system, he did not attempt to motivate any of those systems on the basis of natural-language data. He thought that the K/R-system sufficed for symbolizing the fragment of English for which that system was designed.

Kamp made a similar qualification in his 1971 paper on the *now*-operator [8]. In a widely quoted footnote, he rejected the possibility of symbolizing sentences like *A child was born who will become ruler of the world* by means of symbolizations involving explicit quantification over times. He wrote:

> Such symbolizations, however, are a considerable departure from the actual form of the original sentences which they represent—which is unsatisfactory if we want to gain insight into the semantics of English. Moreover, one can object to symbolizations involving quantification over such abstract objects as moments, if these objects are not explicitly mentioned in the sentences that are to be symbolized.
>
> (Kamp 1971, p. 231, fn. 1 [8])

The *if*-clause of the last sentence suggests that Kamp would not have objected to a symbolization of (8) involving explicit quantification over times.

In short, the doubly-indexed systems of Kamp and Vlach were not designed to formalize overt talk about times in English. Kamp and Vlach proposed these systems for certain fragments of English involving tenses and temporal adverbs like *now* and *then*.[6] They did not hold that any kind of temporal expression that occurs in a sentence must be accounted for in terms of intensional operators. Their intensional approach to tenses and temporal adverbs was compatible with the view that an English sentence which exhibits overt reference to times, or overt quantification over times, at the level of surface syntax must have a formal representation with explicit reference to times and/or explicit quantification over times. An intensional theorist who adopts this view does not have to posit infinite *index*/*then*-operators to account for (8) and its variants.

[6] Prior was interested in the project of expressing overt talk about times by means of tense-logical formalizations. But he invented hybrid logic for that purpose. For some discussion of Prior's views on this matter, see (Blackburn 2006 [3]) and (Blackburn & Jørgensen 2016 [4]).

4 Another Counterexample to Double Temporal Indexing

Let us leave aside any potential counterexample to double temporal indexing which relies on expressions that quantify overtly over times or refer overtly to times at the surface level. Are there English sentences that are not expressible with the aid of doubly-indexed operators and do not involve overt talk about times?

Relevant examples are scarce in the literature. Saarinen (1978, part I [13]) considers a number of interesting examples. (12) is an adaptation of one of his examples.

> (12) Every man who ever supported the Vietnam War will admit that now he believes that he was an idiot then.

Let us assume that the vocabulary of ***L*** includes two Hintikka-style operators $\mathbf{Admit}_s$ and $\mathbf{Believe}_s$ which shift the world of evaluation to a world compatible with what a subject s admits or believes in the world of evaluation at the time of evaluation. If we want to symbolize (12) with *index*/*then*-operators, the subformula **idiot** ***x*** must be evaluated at the past time at which the Vietnam War was supported and the operator $\mathbf{Believe}_x$ must appear under the scope of some temporal operator that retrieves the time of utterance. The semantics has to store these two times and keep them in the semantic memory until the last stages of the computation. But, on the other hand, a future operator must appear in front of $\mathbf{Admit}_x$. If we are using a double-index framework, it follows that one of the two times stored in the semantic memory will have to be deleted by the future operator. To illustrate the point, look at (13).

> (13) $\forall x$ (**man** $x \rightarrow$ H (**support-the-Vietnam-War** $x \rightarrow$ ... F ... $\mathbf{Admit}_x$ ... $\mathbf{Believe}_x$ ... **idiot** x))

Either the time of utterance or the past time associated with H will be deleted by the operator F. Putting doubly-indexed operators in any of the positions marked by the ellipses will not help us to solve this problem. Thus, (12) is a sentence that does not exhibit overt talk about times and seems to be inexpressible in any doubly-indexed extension of ***L***.

However, it is not obvious that one can generate variants of (12) that make infinite temporal indexing mandatory for someone who wants to

represent the English tenses and the adverbs *now* and *then* in terms of intensional operators. The obvious way of generating a relevant variant of (12) is to add an attitude verb and try to make the time of the attitude anaphoric to another time. (14) is an implementation of this strategy.

> (14) Every man who ever supported the Vietnam War will admit that now he believes that he will then know that he was an idiot then.

If we try to generate more variants of (12) by adding to it more attitude verbs and more occurrences of *then* in a systematic manner, the resulting sentences will be increasingly harder to process. If this is so, it is not clear that those sentences make a persuasive case for infinite temporal indexing. Of course, we can generate fully grammatical variants of (12) by introducing overt reference to times. As we have seen, however, sentences involving overt reference to times are not necessarily problematic for the advocate of *index*/*then*-operators.

5 Infinite *Index*/*Then*-Operators

As I explained in the introduction, the second part of Cresswell's argument consists in providing an equivalence proof involving two languages: a predicate-logic language with full quantification over times and an intensional language with infinite temporal indices and infinite *index*/*then*-operators (see Cresswell 1990, chapter 4 [5]).

In two recent papers, Yanovich (2011, 2015 [19, 20]) argues that a first-order modal language with infinite indices and infinite *index*/*then*-operators has less expressive power than an extensional first-order language with full quantification over worlds or times. Yanovich suggests that the widespread belief to the contrary among philosophers and linguists is the result of a misinterpretation of Cresswell's proof. The basic intensional language that Cresswell characterizes in *Entities and Indices* has an operator of universal modality in addition to its *index*/*then*-operators. According to Yanovich, this operator makes the intensional language of Cresswell more powerful than a first-order modal language that employs *index*/*then*-operators but which lacks the operator of universal modality.[7] For our purposes in this note, the crucial observation

[7] For discussion of this point, see esp. Yanovich 2015, sections 1 and 7.

of Yanovich is that the intensional language of Cresswell's proof has at least one operator in addition to the *index*/*then*-operators and the standard operators P, F, H, and G. Moreover, this operator—the operator of universal modality—is not needed in order to symbolize (8) and its variants. The only operators that are needed for this purpose are the standard temporal operators and the *index*/*then*-operators. Consequently, Cresswell's proof does not show that an operator-based language with enough power to symbolize (8) and its variants must be a language with the power of full quantification over times.

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Counterfactuals, Causal Independence and Determinism

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Abstract

In his (2004) paper, Jonathan Schaffer proposes an ingenious remedy to various kinds of counterexamples to Lewis' semantics for counterfactuals. This paper discloses a potential deficiency of that remedy.

1 Problem

In his influential paper 'Counterfactuals, causal independence and conceptual circularity,' Jonathan Schaffer [6] offers an ingenious remedy for various kinds of counterexamples that have been launched against Lewis' semantics for counterfactuals.[1] These counterexamples range from varieties of Kit Fine's nuclear holocaust, via John Hawthorne's compulsive coin-flipper, to sophisticated versions of Morgenbesser's coin. Let us rehearse Schaffer's proposal by applying it to the latter, Morgenbesser's coin:

In some indeterministic world w_{i}, I toss an unbiased coin. While the coin is midair, you bet that it will land heads. Unfortunately, you lose; the coin lands tails.

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At w_i, it now seems right to claim that

1. If you had bet tails (T), you would have won (W).

However, Lewis' semantics has it that:

> *LS* A counterfactual *A*>*C* is true at w iff if *A* is true at any world at all, *A* is true at some *C*-world closer to w than any (A∧¬C)-world; where closeness is to be understood according to the following metric
>
> (i) It is of the first importance to avoid big miracles.
> (ii) It is of the second importance to maximize the region of perfect match.
> (iii) It is of the third importance to avoid small miracles.
> (iv) It is of the fourth importance to maximize the region of imperfect match (Lewis 1979 [2]).[2]

Is (1) true at w_i, according to LS? No, Schaffer correctly points out. For the closest ($T\wedge\neg W$)-world and the closest (T∧W)-world are equidistant from w_i : "Each costs the same miracle of [you] betting tails. Each costs perfect match with actuality from then on, neither costs any further miracles, and each buys an aspect of imperfect match – [one] preserves the outcome of the flip (tails), while [the other] preserves the outcome of the bet (unlucky)" (Schaffer 2004, p. 303). Hence, LS gets things wrong regarding (1). And, what is worse, LS also gets things wrong regarding:

(2) If *you* had tossed the coin (Y), you *might* have won (W).

At w_i, it seems right to assert (2). Yet, the closest ($Y\wedge\neg W$)-world is closer to w_i than the closest ($Y\wedge W$)-world: each costs the same miracle of you tossing. Each costs perfect match with actuality from then on, neither costs any further miracles, but only the former buys imperfect match; it preserves the outcome of the flip *and* the outcome of the bet (tails and unlucky). Hence, according to LS, the following is true at w_i:

[2]Here I follow Shaffer's exposition which differs slightly from Lewis' own formulation. In Lewis (1979), iv) is: "It is of little or no importance to secure approximate similarity of particular fact, even in matters that concern us greatly" (p.472). Lewis regretted that he could not come up with any principled guidelines for how to choose between 'little' and 'no'. Schaffer's amended metric (see below) can be seen as an attempt to rectify this deficiency.

(3) If you had tossed the coin (Y), you would have lost ($\neg W$).

But (3) is incompatible with (2), so (2) comes out false.

2 Remedy

Schaffer's ingenious solution consists in modifying the ordering metric in LS thus:

> (i*) It is of the first importance to avoid big miracles.
> (ii*) It is of the second importance to maximize the region of perfect match, *from those regions causally independent of whether or not the antecedent obtains*.
> (iii*) It is of the third importance to avoid small miracles.
> (iv*) It is of the fourth importance to maximize the spatiotemporal region of approximate match, *from those regions causally independent of whether or not the antecedent obtains*
>
> (Schaffer 2004, p. 305 [6]).

Let us now reevaluate (2) in light of this amendment. The value that imperfect match confers on (Y$\wedge\neg$W)-worlds, and not on (Y$\wedge$W)-worlds, now diminishes drastically. In fact, *this* imperfect match becomes worthless; both the outcome of the flip and the outcome of the bet are causally *dependent* on the obtaining of the antecedent (you tossing the coin) and so do not count for anything according to the amended metric. Thus, the closest ($Y\wedge\neg W$)-world and the closest (Y$\wedge$W)-world become equidistant to w_i. (2) therefore comes out true at w_i as it should do.

Better still, the value that imperfect match confers on the closest ($T\wedge\neg W$)-world, but not on the closest ($T\wedge W$)-world, also vanishes (the outcome of the bet – you losing - is causally dependent on your betting tails). However, the value that imperfect match confers on the closest ($T\wedge W$)-world, but not on, the closest ($T\wedge\neg W$)-world, remains *stable* (the outcome of the toss (tails) is causally *independent* of your betting tails). Hence, now the closest ($T\wedge W$)-world is closer to w_i than the closest ($T\wedge\neg W$)-world, and so (1) also comes out true.

And this is not all. Far from it. Also all the other thorny cases discussed by Schaffer apparently disperse once they are evaluated according to the amended metric. Furthermore, not only is this remedy extremely efficient, it also seems to lacks pernicious side effects. As noted

by Schaffer, this is opposed to other proposed remedies, which require radical departure from LS. Finally, Schaffer argues, the apparent circularity involved in defining counterfactuals in terms of causal dependence (which is standardly defined in terms of counterfactuals) need not be vicious.

This all sounds tremendous. Is this the modal paradise we have all been longing for?

3 Cost

Maybe, but there is a snag. The coin landed tails.[3] And so, following Schaffer, its landing tails is counterfactually implied by you betting tails. This is so since the outcome of the toss is causally independent of your betting behavior.[4] And this point generalizes: for *any P* causally irrelevant for the outcome of the toss, *P* counterfactually implies that the coin would land tails. And it generalizes even further:

(4) For any true *C*, if *C* is causally independent of *A*, *A* counterfactually implies *C*.[5]

Now, invoking causality in an account of counterfactuals may give rise to worries about circularity. Here is Schaffer:

> I have recommended using causal independence in assessing standard counterfactuals. But this sort of recommendation threatens *circularity*, given that many leading approaches to causation (including Lewis 1973c, 1986c and 2000) invoke counterfactuals. (*ibid*, p. 307)

[3] In w_i. In what follows, I shall pretend that w_i is the actual world. That way, we save 7 instances of "at w_i". If you disagree with this sort of sloppiness, feel free to plot them in as appropriate.

[4] Hence, the closest (betting tails & landing tails)-world is closer than the closest (betting tails & not landing tails)-world: the former, but not the latter, buys imperfect match regarding the outcome of the toss (landing tails). And the two worlds are on par regarding the other criteria i*–iii* in the amended closeness metric.

[5] The closest $(A \wedge C)$-world is closer that the closest $(A \wedge \neg C)$-world: the former, but not the latter, buys perfect or imperfect match regarding *C*. And the two worlds are on par regarding the remaining criteria in the amended closeness metric.

Schaffer, however, offers persuasive arguments to the effect that this sort of circularity is not vicious. Yet, invoking causality is still highly problematic for him. At least if what he has in mind is the Lewisian account of causality mentioned in the quote above. According to this account:

LC C is causally dependent on A iff $((A{>}C) \wedge (\neg A{>}\neg C))$[6]

Adopting this Lewisian view of causality, we can rephrase (4) as:

(4*) $(C \wedge \neg((A{>}C) \wedge (\neg A{>}\neg C))) \rightarrow (A{>}C)$[7]

The problem is that (4*) is equivalent with:

(4**) $C \rightarrow (A{>}C)$[8]

Hence, if Schaffer adopts a Lewisian account of causal dependence, his remedy *does* require drastic departure from LS after all. Not only is (4**) highly implausible, it is also inconsistent with LS. Both in its traditional and in Schaffer's amended versions. Consider, for instance:

(5) If the coin had landed tails (T), it would have landed heads (H).

No metric for closeness could adjudicate the closest T-worlds to be H-worlds. Yet, the coin *did* land heads, so (5) is true according to (4**). Moreover, you *did* lose. Hence, by (4**), also (1) and (2) come out false, and so it becomes hard to see that any progress has been made by Schaffer's revised ordering metric.

[6] I here focus on the account developed in (Lewis, 1986b [4]). Although his account from (Lewis, 2000 [5]) is a little more complex, the considerations below could easily be modified to suit that version.

[7] '$\rightarrow$' for material implication.

[8] The logical form of (4*) and (4**) being $(((A \wedge \neg(C \wedge B)) \rightarrow C)$ and $(A \rightarrow C)$, respectively. Both are false iff A is true and C is false. I don't know of any official name for (4**). But 'Determinism' seems appropriate: Given C, things could not have been otherwise regarding C. No matter what.

4 Conclusion

I have shown that Schaffer's proposal, although highly efficient and intuitively appealing, has a potential deficiency. Combined with a Lewisian account of causality, it leads to drastic and implausible revisions (4**). This may be seen as only a minor limitation of Schaffer's proposal. There are, after all, more candidates to choose between. However, one may fear that *other* counterfactual accounts of causality give rise to similar problems. And, worse, that even non-counterfactual accounts may *imply* basic counterfactual claims which, in turn, will issue in similar troubles. But that, of course, is only speculation until we have seen *which* account of causality is to be recommended.[9]

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[9] Thanks to $NN_1$and NN_2 for stimulating discussions and helpful comments.

The coat problem. Counterfactuals, truth-makers, and temporal specification

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Abstract

Standard semantic treatments of counterfactuals appeal to a relation of similarity between possible worlds. Similarity, however, is a vague notion. Lewis suggests reducing the vagueness of similarity by adopting a principle known as 'late departure' (LD): the more the past two worlds share, the more they are similar. LD has several virtues. However, as Bennett points out, a standard semantics based on LD suffers from the so-called coat problem. In a nutshell, we are led to assign counterintuitive truth-values to counterfactuals whose antecedent time is left underspecified. In the present paper, we argue that the coat problem may be solved by defining a time-sensitive notion of similarity. To illustrate, we assume a Priorean, tensed language, interpreted on branching-time frames in the usual, 'Ockhamist' way, and we enrich it with a counterfactual connective. Within this framework, we define a time-sensitive relation of similarity, based on Yablo's work on truth-makers and partial truth. In the resulting semantics, which has independent interest, the coat problem does not arise.

Keywords: Branching-time, Counterfactuals, Truth-maker, Partial truth

1 A problem for the late departure principle

By a *counterfactual* we mean a subjunctive conditional 'If $\mathcal{A}$ were the case, $\mathcal{B}$ would be the case' ($\mathcal{A} \mathrel{\square\!\!\rightarrow} \mathcal{B}$) with false antecedent (see, e.g., [13, 173]). Here is the standard semantic clause for counterfactuals, as developed in [12]:

Standard counterfactual semantics (**CS**):
$\mathcal{A} \mathrel{\square\!\!\rightarrow} \mathcal{B}$ is true at a world w iff:

(a) either w has no access to any $\mathcal{A}$-world (the vacuous case); or
(b) some $(\mathcal{A} \wedge \mathcal{B})$-world is more similar to w than any $(\mathcal{A} \wedge \neg\mathcal{B})$-world.

Comparative similarity (with the world of evaluation) is a key ingredient of **CS**. Similarity, however, may be unsatisfying, for it displays a high degree of vagueness. As Lewis [10] points out, the vagueness of similarity cannot be entirely dispelled, for counterfactuals are intrinsically vague. Nevertheless, it can be significantly attenuated.

A first step in this direction is that of characterising comparative similarity as a reflexive and transitive relation, that is, as a preorder. Moreover, as Lewis [11] points out, the vagueness of similarity can be further reduced. Let us focus on *non-backtracking* counterfactuals, that is, roughly, counterfactuals whose antecedents are about eventualities that obtain before (or simultaneously with) the eventualities the consequents are about, as in "If John missed the train, he would still be in London". Non-backtracking counterfactuals, Lewis contends, are evaluated against possible antecedent scenarios that keep, as far as possible, the actual past fixed (for a study providing empirical support to Lewis's insight, see [7]). According to Lewis, in assessing these counterfactuals, we should focus on those worlds that share with the actual world as much of their past as possible, except for the stretch of time strictly needed to make the antecedent true. If Lewis is right, then, it is natural to require that the similarity relation satisfy the following principle (this and the other principles we discuss are assumed to hold for non-backtracking counterfactuals and to impose *ceteris paribus* conditions on similarity):

Late departure principle (**LD**):
The more the past two worlds share, the more they are similar.[1]

[1] See [13] for a counterfactual semantics that encodes principle **LD**.

It is easy to refine principle **LD** in formal terms. A very natural mathematical background against which **LD** can be refined is that of the so-called branching-time frames. In this paper, we discuss versions of principle **LD** that are made precise within these frames.

To sum up, principle **LD** helps to reduce the vagueness of similarity, it appears to be involved in counterfactual reasoning, and it has rigorous, formal translations. One may be tempted, then, to assume **LD** with full confidence. Unfortunately, **LD** is problematic.

As Bennett [2] shows, if **LD** is taken to determine the relation of similarity (and assuming something like a branching conception of time), the resulting counterfactual semantics suffers from the so-called *coat problem*. Suppose that John's coat was not stolen from the restaurant where he left it. Moreover, assume that there were just two, equally good, chances for it to be stolen, the former at 1 pm and the latter at 1:30 pm. If the coat were stolen at 1:30 pm, then the thief would sell the coat to a pawnbroker named Fence. Since the latter chance for theft is the one that would obtain later, it obtains in the latest world departing from actuality, among those where the coat is stolen. Thus, if **LD** is adopted, **CS** predicts the truth of:

(1) If John's coat had been stolen, it would now be in Fence's shop.

Intuitively, this result is unwelcome. If we take **CS** for granted, we can conclude that **LD** leads to counterintuitive results. This is the *coat problem*.

In this paper we argue that the coat problem does nothing to undermine the key motivations that justify principle **LD**. Rather, it just shows that **LD** is not general enough, that there are limits in the kind of cases it can be sensibly applied to. In [13, 191] it is suggested that the the coat problem highlights a difficulty of **LD** that eludes formal treatment. In our view, this suggestion is too hasty. As we shall see, once the limits of **LD** are put to the fore, it is possible to define a more general principle, which retains all the virtues of **LD** and vindicates the same basic insights without falling prey to the coat problem.

A disclaimer. It is not part of our aim to offer a variant of **LD** that escapes *any* known difficulty. To be sure, the coat problem is not the only problem that must be solved (or at least put into perspective) if **LD** and similar principles are to be applied to a sufficiently wide range of cases (see, for instance, the so-called late departure problem discussed in [13]

and [16]). However, as far as we can see, there is no problem affecting our variant, which does not affect **LD** as well.

2 A Priorean revision of the late departure principle

In the celebrated paper *Identifiable individuals* [14], Prior discusses the view that a person could have had different parents than the ones he actually had. According to Prior, in assessing counterfactual hypotheses of this kind, philosophers are often led to neglect a key issue. In his own words:

> It is always a useful exercise (and one insufficiently practised by philosophers), when told that something was possible, i.e. could have happened, to ask '*When* was it possible?' '*When* could it have happened?' (70)

This recommendation has deep connections with other key contributions from Prior, such as his seminal works in the semantics and metaphysics of historical modality.

We suggest that the coat problem depends precisely on the oversight Prior mentions in the above quote, that is, neglecting the role of time in assessing modal claims. Exactly as the modal properties of certain individuals may change across time (as Prior observes), so may change the relative similarity of certain worlds. With this in mind, consider the following principle.

LD* The more the past two worlds *do not* share, the more they are *dis*similar.

Under reasonable assumptions, **LD*** is equivalent to **LD**. Nonetheless, **LD*** and **LD** interact in a different way with Prior's recommendation, as the former is much easier to turn into a principle connecting time and (dis)similarity. Here is the principle, that is, the time-relativised version of **LD***:

Dynamic late departure principle (**DLD**): The more the past two worlds do not share *at a given time*, the more they are dissimilar *at that time* (or, if you prefer, *up to* that time).

To make **DLD** precise, we need to define a formally respectable, time-sensitive relation of past-(not-)sharing. To this aim, we adopt a branching-time conception, in which worlds are identified with *histories*, that is, spatially and temporally complete courses of physical events. A branching time structure or *tree* is, roughly, a bunch of histories that share an initial, 'past' part and divide afterwards, yielding different branches.

If h is the actual history (i.e., the history of evaluation) and h' is a history divided from h at time t, we call a *non-actual stretch* of h' the part of h' that goes from t to the time of branching between h and h' (which we indicate as $h_{\curlyvee}h'$, see figure 1).[2] By **DLD**, the shorter the non-actual stretch of h' at t is, the more similar h' is to actuality at t.

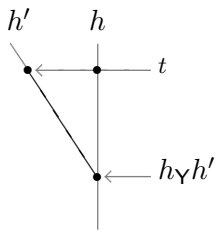

Figure 1: The non-actual stretch of h' at t (highlighted in black).

Before returning to the coat problem, let us spend a few words of comment on principle **DLD**. Admittedly, **DLD** is conceptually more costly than **LD**, for it requires that different histories be temporally comparable or 'synchronised' (see below, p. 4). However, there are independent reasons to pay the price (see, e.g., [4, 265–266]). Once synchronised trees are adopted, it is hard to see why someone who leans towards **LD** may be willing to reject its time-relativised version **DLD**. After all, for any time t, if we use **LD** and **DLD** to measure the comparative similarity of two histories that are divided at t, then the two principles yield precisely the same verdict. In addition to that, **DLD** allows us to compare distinct histories relative to different times—a kind of comparison that makes perfect sense within the branching-time conception. As we shall argue in the next section, this feature of **DLD** is key to solving the coat problem.

[2] We assume a discrete temporal ordering. For a formal definition of trees, see § 4.

3 Outline of a solution to the coat problem

Let us familiarly speak of an *antecedent truth-maker* to indicate an event that would make the antecedent true, and let us speak of an *antecedent time* to indicate the time at which a truth-maker of the antecedent obtains (for more precise characterisations of these notions, see below, §§ 5 and 6).[3]

Consider again the scenario described by Bennett, as represented in figure 2. John's coat is not stolen in the actual history h but might have been in two specific occasions, O_1 (which would obtain only at 1 pm on h_1) and O_2 (only at 1:30 pm on h_2). Both O_1 and O_2 are antecedent truth-makers. Let us assume that h_1 is the O_1-history that has the shortest non-actual stretch at the relevant antecedent time 1 pm. Analogously, h_2 is the O_2-history that has the shortest non-actual stretch at antecedent time 1:30 pm. In figure 2, the non-actual stretch of h_1 at 1 pm is the distance from 12:45 pm (time $h_{\curlyvee}h_1$) to 1 pm (the antecedent time corresponding to O_1), and the non-actual stretch of h_2 at 1:30 pm is the distance from 1:15 pm (time $h_{\curlyvee}h_2$) to 1:30 pm (the antecedent time corresponding to O_1). Both stretches are 15 minutes long. The coat now would be in Fence's shop (scenario S) if, and only if, O_2 had obtained.

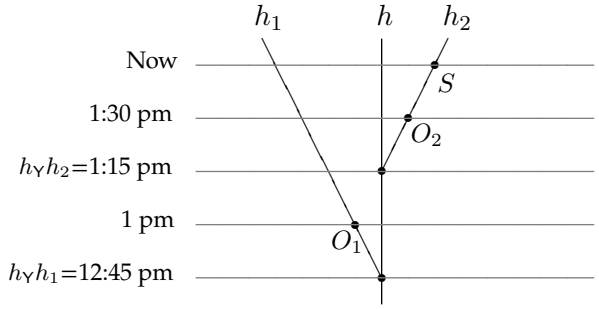

Figure 2: A partial representation of Bennett's scenario.

This is Bennett's counterfactual:

(1) If John's coat had been stolen, it would now be in Fence's shop.

It has been noted that the antecedent of (1) is underspecified, in that

[3] In [6], Kit Fine adopts a counterfactual semantics based on the so-called truth-maker semantics. Our proposal differs from Fine's account, for it mixes possible worlds semantics with truth-maker semantics. For a similar approach, see [5].

there are two distinct antecedent truth-makers O_1 and O_2 (see, e.g., [8]). More importantly for us, the antecedent is *temporally* underspecified, as there are two different antecedent times, 1 pm and 1:30 pm. We can make this temporal underspecification explicit by replacing (1) with:

(2) If John's coat had been stolen either at 1 pm or at 1:30 pm, it would now be in Fence's shop.[4]

When the antecedent time is uniquely specified, **LD** measures precisely what it is supposed to measure: how long a counterfactual history has to be divided from actuality to make the antecedent true. When the antecedent time is underspecified, however, **LD** may go astray. This is precisely what happens in the coat problem. By **LD**, h_2 is deemed closer to actuality than h_1 just because the time of O_2 is later than that of O_1. Thus, by **CS**, it turns out that (2) is true, against common intuitions. Now, let us see why **DLD** fares better than **LD** in this respect. As just seen, (2) is temporally underspecified in that it has two antecedent times. Accordingly, the task of evaluating (2) boils down to the following tasks:

(i) consider 1 pm, that is, the antecedent time of the truth-maker O_1, and assign to the O_1-histories a measure of similarity with actuality at 1 pm;
(ii) repeat the same operation with the antecedent time of the truth-maker O_2;
(iii) apply **CS** to all antecedent histories, using the measures of similarity assigned at points (i), (ii).

It should be clear that, differently from **LD**, the variant **DLD** we are proposing is perfectly adequate for tasks (i) and (ii). In a branching-time structure, if h is the actual history, for each antecedent history h' with antecedent time t, there exists a unique non-actual stretch of h' at t. By **DLD**, the length n of this stretch counts as a measure of dissimilarity from actuality. Thus, we are in a position to apply **CS** in the usual way: a counterfactual $\mathcal{A} \mathrel{\Box\!\!\rightarrow} \mathcal{B}$ is presently true iff $\mathcal{B}$ is true in all $\mathcal{A}$-worlds whose measure n is smaller than that of any $\mathcal{A}$-world in which $\mathcal{B}$ is false.

[4] It has been recently argued that counterfactuals with disjunctive antecedent pose serious problems to any semantics based on **CS** (see, e.g., [3]). Albeit we think that these problems are worth considering, discussing them is beyond the scope of this paper.

DLD enables to get the coat story right: since the non-actual stretch of h_1 at the (antecedent) time of O_1 is as long as that of history h_2 at the (antecedent) time of O_2, both histories count as equally similar to actuality. Since S is true at h_2 only, however, statement (2) (or, equivalently, (1)) is false at the actual history. Notice that when the antecedent is not temporally underspecified—when a unique antecedent time exists—**DLD** and **LD** agree on the similarity ordering. In the next section we outline a formal version of this preliminary analysis.

4 Counterfactuals and branching-time structures

As said above, our solution requires that all histories in the tree are temporally comparable. Accordingly, we choose a suitable brand of branching-time structures, viz., *sinchronised* trees (see [4, 269–273], see also [1, 195–196]).

A synchronised tree $\mathcal{T}$ is defined as a tuple $(M, \preceq, d)$, where M is a nonempty set of entities called moments, and $\preceq$ is a partial order on M, which corresponds to the (improper) precedence relation on M ($\prec$, $\succeq$, and $\succ$ are defined in the obvious way). To keep the formal complexity to a minimum, we assume that $\preceq$ is a *discrete* ordering. Nothing philosophically important hinges on this assumption. A *history* is defined as a maximal set of moments in $\preceq$. Moreover, letting m, m' and m'' vary over moments:

(a) if $m' \not\preceq m''$ and $m'' \not\prec m'$, some m is such that $m \prec m'$ and $m \prec m''$;
(b) if $m' \prec m$ and $m'' \prec m$, either $m' \preceq m''$, or $m'' \prec m'$;
(c) histories are all isomorphic;
(d) a *time* t is a set of moments that intersects each history at precisely one moment. We also write t_h to indicate the moment in $t \cap h$.
(e) times preserve the order of the corresponding moments (that is, $t_h \prec t'_h$ entails $t_{h'} \not\succeq t'_{h'}$). We shall say that t is earlier than t' iff $t_h \prec t'_h$ for some h.

d is a metric function that assigns to any pair (t, t') of times a non-negative number n expressing the temporal distance between t and t' (see [9] for details). We require that $t' = t''$ iff $t_h \prec t'_h, t''_{h'}$ entails $d(t, t') = d(t, t'')$.

The language $\mathcal{L}_T$ is a standard tensed propositional language endowed with a set $Atom$ of countable atoms $p, q, p_1, \ldots$, and with two sentential operators P ('Sometimes in the past') and F ('Sometimes in

the future'). We indicate as H and G the duals of P, F, respectively. As usual, atoms are thought of as simple, present tensed sentences that contain no 'trace of futurity'.

A standard semantics for $\mathcal{L}_T$ is Prior's [15] *Ockhamist semantics*, which evaluates sentences of $\mathcal{L}_T$ at moment-history pairs. An Ockhamist model is a tuple $\mathfrak{M}_{\mathsf{O}} = (\mathcal{T}, \mathcal{I})$, where $\mathcal{T}$ is a tree and $\mathcal{I}$ an interpretation function from $Atom \times M$ onto the set $\{0, 1\}$ of truth-values. Elements of $\mathcal{I}$ are called *assignments*. Ockhamist truth is defined in the usual, recursive way (clauses for booleans and reference to models are omitted; we abbreviate $\{t_h, h\}$ as t/h):

$$
\begin{array}{lll}
t/h \vDash p & \text{iff} & \mathcal{I}(p, t_h) = 1; \\
t/h \vDash \mathsf{P}\mathcal{A} & \text{iff} & \exists t'(t'_h \prec t_h \ \& \ t'/h \vDash \mathcal{A}); \\
t/h \vDash \mathsf{F}\mathcal{A} & \text{iff} & \exists t'(t_h \prec t'_h \ \& \ t'/h \vDash \mathcal{A}).
\end{array}
$$

Now, let us enrich $\mathcal{L}_T$ with connective $\Box\!\!\rightarrow$, yielding language $\mathcal{L}_{TC}$. The syntax of $\mathcal{L}_C$ is defined in the obvious way. We ignore complications that depend on embedding counterfactuals one into another.

To interpret $\mathcal{L}_{TC}$ in accordance with the Ockhamist semantics, counterfactuals are themselves to be evaluated relative to moment-history pairs. As argued in [16, 182–185], the moments that are relevant for assessing $\mathcal{A} \Box\!\!\rightarrow \mathcal{B}$ at a point t/h are those located at t. Clause **CS** must be modified accordingly:

CS* $t/h \vDash \mathcal{A} \Box\!\!\rightarrow \mathcal{B}$ iff

(a) either no t/h' satisfies $\mathcal{A}$, for any history h', or
(b) some $(\mathcal{A} \wedge \mathcal{B})$-point t/h' is strictly more similar to t/h than any $(\mathcal{A} \wedge \neg\mathcal{B})$-point t/h''.

For our purposes, claims about the similarity of two points t/h and t/h' boils down to claims concerning the similarity of histories h and h' up to time t.

5 Similarity, truth-makers, and antecedent times

Clause **CS*** requires that a notion of comparative similarity between moment-history pairs be provided. Both **LD** and **DLD** can be used to perform this task.

Let us start with **LD**. Recall that histories branch off from one another only towards the future. Thus, to say that the more the past two

worlds share the more they are similar amounts to saying that the more the moments two histories share, the more they are similar. Let us call LD-similarity the notion of comparative similarity that we can distil along these lines. Formally, h' is at least as LD-similar to h as h'' iff $h' \cap h \supseteq h'' \cap h$ (see [13] and [18]). Based on LD-similarity, it is straightforward to define a comparative notion of LD*-similarity between antecedent moment-history pairs: $\mathcal{A}$-point t/h' is as LD*-similar to t/h as $\mathcal{A}$-point t/h'' if and only if h' is as LD-similar to h as h''.

To get a semantics for counterfactuals, it is sufficient to identify the similarity relation in **CS*** with LD*-similarity. As expected, the resulting semantics falls prey to the coat problem. If h, h_1 and h_2 are as in figure 2, then the following formal version of (2) turns out to be true at Now$/h$:

(3) $(\mathsf{P}o_1 \vee \mathsf{P}o_2) \,\Box\!\!\rightarrow s$

Let us now consider **DLD**. We start by offering a formal counterpart of the above, intuitive notion of a truth-maker, based on Yablo's work [17, Chap. 4]. We identify a truth-maker of $\mathcal{A}$ at t/h ($\mathsf{tmk}(\mathcal{A}, t/h)$ in symbols) with a *minimal model* of $\mathcal{A}$ at t/h. In turn, a minimal model is a set of assignments that is, intuitively, as small as is strictly necessary to make $\mathcal{A}$ true at t/h. More formally, given a model $\mathfrak{M}_O = (\mathcal{T}, \mathcal{I})$, a truth-maker $\mathsf{tmk}(\mathcal{A}, t/h)$ is a set of assignments such that:

(i) $\mathsf{tmk}(\mathcal{A}, t/h) \subseteq \mathcal{I}$;
(ii) if an Ockhamist model $\mathfrak{M}'_O = (\mathcal{T}, \mathcal{I}')$ is such that $\mathsf{tmk}(\mathcal{A}, t/h) \subseteq \mathcal{I}'$, then $\mathfrak{M}'_O, t/h \vDash \mathcal{A}$;
(iii) if f is a set of assignments such that $\mathsf{tmk}(\mathcal{A}, t/h) \supset f$, then some Ockhamist model $\mathfrak{M}'_O = (\mathcal{T}, \mathcal{I}')$ is such that $\mathcal{I}' \supset f$ and $\mathfrak{M}'_O, t/h \nvDash \mathcal{A}$.

If a truth-maker assigns a value to a pair (p, t_h), we shall say that it *covers* time t (on h). Moreover, a set f is a *possible truth-maker* of $\mathcal{A}$ at t/h in $\mathfrak{M}_O = (\mathcal{T}, \mathcal{I})$ if, for some Ockhamist model $\mathfrak{M}'_O = (\mathcal{T}, \mathcal{I}')$, f is a truth-maker of $\mathcal{A}$ at t/h in $\mathfrak{M}'_O$. We indicate a possible truth-maker of $\mathcal{A}$ at t/h as $\Diamond\mathsf{tmk}(\mathcal{A}, t/h)$.

Some comments are in order. First, if a sentence $\mathcal{A}$ is true at a point, there exists at least one truth-maker of $\mathcal{A}$ at that point. However, a sentence can have more than one truth-maker at a point. For instance, there are exactly two possible truth-makers of $(p \vee \neg q)$ at t/h, namely,

$\{(p, t_h) \mapsto 1\}$ and $\{(q, t_h) \mapsto 0\}$. If $(p \vee \neg q)$ is true at t/h, at least one of these possible truth-makers is also actual. But nothing forbids both from being actual.

Second, $\mathsf{tmk}(\mathcal{A}, t/h)$ need not cover time t. Consider, for instance, $\mathsf{P}p$ at point t/h, and suppose that $\mathcal{I}(p, t'_h) = 1$, with $t'_h \prec t_h$. Then, $\{(p, t'_h) \to 1\}$ is a truth-maker of $\mathsf{P}p$ at t/h but does not cover t at all.

Third, a truth-maker may cover more than one time. Suppose, for instance, that $(p \wedge \mathsf{P}q)$ is true at t/h. If so, its truth-makers at t/h must cover exactly two times, that is, be of form $\{(p, t_h) \mapsto 1, (q, t'_h) \mapsto 1\}$ (with $t'_h \prec t_h$).

To see how truth-makers enable us to deal with temporal underspecification, let us start by assessing counterfactual (3) against the tree in figure 2. There are two truth-makers of the antecedent of (3) at time Now:

(i) $\{(o_1, 1\,\mathrm{pm}_{h1}) \mapsto 1\}$, corresponding to occasion O_1; and
(ii) $\{(o_2, 1{:}30\,\mathrm{pm}_{h2}) \mapsto 1\}$, corresponding to O_2.

The measure of similarity with actuality of Now/h_1 and Now/h_2 is given by the distance between the time covered by the antecedent truth-maker on each history and the time at which that history divides from actuality. Since the distance is the same (15 minutes), point Now/h_1 is as similar to actuality as point Now/h_2.

Let us generalise this account. We define antec' as a function from triples $(\mathcal{A}, t/h', h)$ (where t/h' is assumed to be an antecedent $\mathcal{A}$-point and h is the actual history) to times such that:

- if the earliest time t^* covered by some truth-maker of $\mathcal{A}$ at t/h' is later than the time of branching $h_{\curlyvee}h'$, then $\mathsf{antec}'(\mathcal{A}, t/h', h) = t^*$;
- $\mathsf{antec}'(\mathcal{A}, t/h', h)$ is undefined otherwise.

Intuitively, antec' is (our first shot at) a formal counterpart of the notion of an antecedent time. Let us note that $\mathsf{antec}'(\mathcal{A}, t/h', h)$, if defined, is required to be later than the time of branching between h and h'. Since we characterised counterfactuals as conditionals with false antecedents, we may assume that the antecedent time on a history h' should be later than the time at which h' divides from the actual history h. Now, let us define a similarity mapping siml', as follows, where t/h' is an $\mathcal{A}$-point:

$$\mathsf{siml}'(\mathcal{A}, t/h', h) = d(h_{\curlyvee}h', \mathsf{antec}'(\mathcal{A}, t/h', h)).$$

The values $\mathsf{antec}'(\mathcal{A}, t/h', h)$ and $\mathsf{sml}'(\mathcal{A}, t/h', h)$ are defined only if the earliest time covered by some truth-maker of $\mathcal{A}$ at t/h' is after the time of branching between h and h'. We are now in a position to specify a relation of comparative similarity between antecedent points:

DLD′-similarity $\mathcal{A}$-point t/h' is at least as similar to actuality t/h as $\mathcal{A}$-point t/h'' iff $\mathsf{sml}'(\mathcal{A}, t/h', h) \leq \mathsf{sml}'(\mathcal{A}, t/h'', h)$.

If the similarity relation in **CS*** is DLD-similarity, the resulting semantics does not fall prey to the coat problem.

Thus, it is tempting to suppose that DLD′-similarity is precisely the notion we were looking for. This is false, however, as we are going to argue in the next section.

6 Antecedent times and partial truth

To see why DLD′-similarity is unsatisfying, an example may be useful. Let then $\mathsf{H}p$ be the formal version of "Always in the past, the Moon was free from human footprints", and consider counterfactual $\mathsf{H}p \mathbin{\Box\!\!\rightarrow} \mathcal{B}$. Let t_h be the present, actual point, and let t'_h be the moment on July 20, 1969 of Armstrong's celebrated 'one small step' on the Moon. Clearly, on h, sentence p is always true up to t', it becomes false at t', and is always false from t' onwards. Now, consider an antecedent point t/h'. Since p is always true in the past of $t_{h'}$, there exists no $\mathsf{antec}'(\mathsf{H}p, t/h', h)$ that is later than $h'_{\mathsf{Y}}h$. As a consequence, sml' is undefined for argument $(\mathsf{H}p, t/h', h)$, and we cannot assign to t/h' any measure of similarity to actuality. The problem is that our 'official' notion of antecedent time, antec', is in wait of substantial refinement.

To best appreciate the reason why antec' goes astray, it is useful to introduce a novel notion, that of *partial truth* (see also [17, Ch. 5]). Let us say that a sentence $\mathcal{A}$ is partially true at a point t/h in model $\mathfrak{M}_O$ if, for some assignment $f \in \mathcal{I}$, f is an element of a possible truth-maker of $\mathcal{A}$ at t/h in $\mathfrak{M}_O$. More formally:

Partial truth $\mathcal{A}$ is *partially true* at a point t/h in model $\mathfrak{M}_O$ iff, for some $\Diamond\mathsf{tmk}(\mathcal{A}, t/h)$ in $\mathfrak{M}_O$, we have that $\Diamond\mathsf{tmk}(\mathcal{A}, t/h) \cap \mathcal{I} \neq \emptyset$. Intersection $\Diamond\mathsf{tmk}(\mathcal{A}, t/h) \cap \mathcal{I}$ is called a *partial truth-maker* of $\mathcal{A}$ at t/h. A *non-empty* partial truth-maker of $\mathcal{A}$ is also called a *true part* (of content) of $\mathcal{A}$.

The antecedent of counterfactual $\mathsf{H}p \mathrel{\Box\!\!\rightarrow} \mathcal{B}$, unlike the other examples we have considered thus far, is partially true at t/h. Its true part is the set of assignments $\{(t'_h, p) \mapsto 1 : t'_h \prec t_h\}$. In general, DLD′-similarity does not work with counterfactuals whose antecedent is *not completely* false. The reason is that, intuitively, DLD′-similarity is only sensitive to the antecedent truth-makers that cover times on antecedent histories. In counterfactual reasoning, however, we are not interested only in what happens on antecedent histories. Rather, we are crucially interested in the *differences* between antecedent and actual histories—more specifically, in the differences that are *determined by the truth of the antecedent*. Antecedent times, in turn, may be thought of as times at which such differences (begin to) surface. Thus, when singling out antecedent times, we must forget about the parts of the antecedent (as it were) that are true in both the actual and the antecedent histories, for these parts correspond to no genuine difference.

Let us try to make these casual remarks more precise. To this aim, the following definitions are useful:

Completion If g is a possible truth-maker of $\mathcal{A}$ at t/h and $f \subseteq g$ is a partial truth-maker of $\mathcal{A}$ at t/h, we call *completion* of $\mathcal{A}$ at t/h the difference $g - f$.

Copy If f is a set of assignments on history h', the *copy* of f on h is the set obtained by replacing, for each time t covered by some $a \in f$, the moment $t_{h'}$ in the argument of a with t_h.

Difference-maker A h-difference-maker of $\mathcal{A}$ at t/h' is a subset f of a truth-maker of $\mathcal{A}$ at t/h' such that the copy of f on h is a completion of $\mathcal{A}$ at t/h.

To illustrate, let us assume that h is the actual history and t/h' is an antecedent $\mathcal{A}$-point. A completion of $\mathcal{A}$ at t/h is, intuitively, the minimal set of assignments that need to be added to a partial truth-maker of $\mathcal{A}$ at t/h to turn it into a possible truth-maker of $\mathcal{A}$ at t/h. The h-difference-maker of $\mathcal{A}$ at t/h' is a minimal set of assignments on h' that, intuitively, if copied on the actual history h, would make $\mathcal{A}$ true at the actual point t/h. Note that if $\mathcal{A}$ is completely false at t/h, then all truth-makers of $\mathcal{A}$ at t/h' are h-difference-makers of $\mathcal{A}$ at t/h'.

Let us turn to the resulting, refined notion of antecedent time. If h is the actual history and t/h' is an $\mathcal{A}$-point, we let $\mathsf{antec}(\mathcal{A}, t/h', h)$ be

the earliest time covered by some h-difference-maker of $\mathcal{A}$ at t/h'. In the Moon example discussed above, $\mathsf{antec}(\mathsf{H}p, t/h', h)$ is, intuitively, the time of the earliest assignment that we must modify in $\mathcal{I}$ to make $\mathsf{H}p$ actually true at t. Of course, $\mathsf{antec}(\mathsf{H}p, t/h', h)$ is the time of Armstrong's 'one small step'.

By appeal to this difference-sensitive notion of antecedent time, we may define the following, refined counterparts of siml' and of **DLD**′-similarity, respectively:

$$\mathsf{siml}(\mathcal{A}, t/h', h) = d(h_{\curlyvee}h', \mathsf{antec}(\mathcal{A}, t/h', h));$$

DLD-similarity $\mathcal{A}$-point t/h' is at least as similar to actuality t/h as $\mathcal{A}$-point t/h'' iff $\mathsf{sml}(\mathcal{A}, t/h', h) \leq \mathsf{sml}(\mathcal{A}, t/h'', h)$.

Since DLD-similarity of an $\mathcal{A}$-point t/h' to actuality is inversely proportional to the length of the non-actual stretch of h' at the antecedent time, DLD-similarity vindicates the basic insights behind **DLD**. Besides, DLD-similarity helps to get the role of partial truth in counterfactual reasoning right.

Partial truth antecedents, moreover, highlight an interesting difference between the notions of antecedent time encoded by antec and by antec'. When $\mathcal{A}$ is completely false at t/h and the antecedent time on h' is later than $h_{\curlyvee}h'$, then $\mathsf{siml}(\mathcal{A}, t/h', h) = \mathsf{siml}'(\mathcal{A}, t/h', h)$. If $\mathcal{A}$ is completely false at t/h, indeed, every copy on h of a truth-maker of $\mathcal{A}$ at t/h' is a completion of the unique partial truth-maker of $\mathcal{A}$ at t/h (viz., a completion of $\emptyset$). Accordingly, every truth-maker $\mathsf{tmk}(\mathcal{A}, t/h')$ is a h-difference-maker of $\mathcal{A}$ at t/h', and so the antecedent times we get by antec' and antec coincide.

In the face of it, one may be tempted to hold that, if the antecedent time we get by antec' on h' is later than $h_{\curlyvee}h'$, then it must coincide with the antecedent time we get by antec on h'. This is not so, however. Consider the tree in figure 3, where $(\mathsf{P}p \wedge \mathsf{P}q)$ is false at t/h (for q never holds on h), but not completely so (for p holds at point t''/h, which lies in the past of t/h).

The (unique) truth-maker of $(\mathsf{P}p \wedge \mathsf{P}q)$ at t/h' is the set of assignments $\{(p, t''_{h'}) \mapsto 1, (q, t'_{h'}) \mapsto 1\}$, and the earliest time it covers is t''. Accordingly, $\mathsf{antec}'((\mathsf{P}p \wedge \mathsf{P}q), t/h', h) = t''$. However, the only h-difference-maker of $(\mathsf{P}p \wedge \mathsf{P}q)$ at t/h' is $\{(q, t'_{h'}) \mapsto 1\}$, for copying it on h

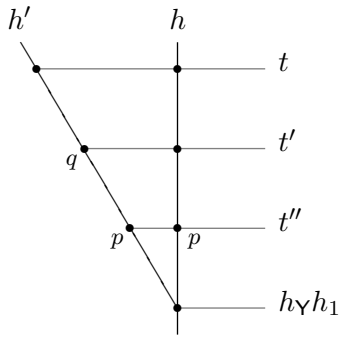

Figure 3: A partial representation of a tree, where atoms p and q never hold, except at the specified points.

is sufficient for making $(\mathsf{P}p \wedge \mathsf{P}q)$ true at the evaluation point t/h. Therefore, $\mathsf{antec}((\mathsf{P}p \wedge \mathsf{P}q), t/h', h) = t'$, and thus $\mathsf{antec}((\mathsf{P}p \wedge \mathsf{P}q), t/h', h) \neq \mathsf{antec}'((\mathsf{P}p \wedge \mathsf{P}q), t/h', h)$.

This result highlights that antec is sensible to differences between actuality and antecedent histories that antec′ cannot detect. Intuitively, for each actual point t/h and antecedent point t/h', antec picks up the time at which a difference between h and h' surfaces, which explains why the antecedent is true at t/h' as opposed to t/h.

7 Conclusions

In this paper, we have introduced and discussed a 'dynamic' version **DLD** of the late departure principle. **DLD** allows us to distil a notion of comparative similarity between histories, which we called DLD-similarity. As we have shown, a counterfactual semantics based on DLD-similarity retains all the virtues of that based on LD-similarity, but it also accounts for counterfactuals whose antecedent time is underspecified.

We have argued that this difference is key to solving Bennet's coat problem.

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Kant on Time and Change: A Series, B Series, or Both?

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Abstract

When interpreters orient Kant in relation to contemporary philosophy of time, they claim that the B series is dependent on the A series. However, I claim that the opposite direction of dependence is also supported, due to Kant's position that change is both intelligible and involves incompatibility. This paper extends the contemporary description of Kant's philosophy of time to show that Kant endorses the interdependence of A series and B series views on time.

Keywords: Kant, A series, B series, Idealism, Change, Contradiction

1 Introduction

This paper argues that the properties and relations that constitute the A and B series are interdependent in Kant's philosophy of time. Arthur Melnick (2004 [12]) and Ralph Walker (2017 [15]) claim that Kant's idealism implies that B series relations depend on A series properties. Interestingly, the issue of whether the A series properties might also depend on the B series relations is not explicitly discussed in the Kant literature. My interpretation claims that the dependence of A series properties on B series relations stems from two of Kant's commitments about change: change is the combination of incompatible predicates in a single subject, and change is intelligible. Taking this together with the results

from Melnick and Walker, this supports an interpretation in which A series properties and B series relations are interdependent.

Kant did not frame his philosophy of time around the distinction between A series properties and B series relations. Despite this, we can use these categories to try to capture an aspect of the issues that Kant attempted to address in his theory of time. Contemporary discussions of the A series / B series distinction are formulated in terms of various metaphysical commitments that are sometimes also combined with semantic claims. L.A. Paul (2010 [13]) emphasizes issues about the relationship between A series properties, the relation of temporal passage, and B series relations (333–334 and 337, [13]). Natalja Deng (2017, [10]) characterizes the B series proponent as holding the position that all times exist and that the B-theoretic descriptions of the world are privileged (p. 239, [10]). As Kant very rarely makes any claims about language in the *Critique of Pure Reason* [1], we will focus on the metaphysical side of the issue. Moreover, following the Kantian literature, this discussion will only concern the status of A series properties and B series relations and not the opposition between eternalist and non-eternalist positions.

I hope to show that Kant's insights into time and change enable a fruitful perspective on the A series / B series debate.[1] An opposition between A series proponents and B series proponents dominates contemporary discussions of philosophy of time. For example, Arthur Prior insisted that the language of the A series was more fundamental as a description of reality than the language of the B series, and this insistence was based on his desire to account for change.[2] In general, endorsement of the A series can be seen as an expression of a commitment to the fundamental reality of change because descriptions of B series relations are eternal truths when true. Kant's position provides an interesting foil to the contemporary narrative on the A series: reflection on his dynamic account of change can be shown to motivate the dependence of the A series properties on B series relations. This is not to say that B series relations are more fundamental than A series properties; his position can be understood as one in which neither is more fundamental than the other. Relatedly, this discussion does not assume that dependence

[1] McTaggart (1908) cites Kant in his seminal paper that develops the distinction. See McTaggart, "The Unreality of Time", 31 [11].

[2] For a representative passage of argumentation that indicates this point, see Prior, "Thank Goodness That's Over", 13 [14].

is an asymmetric relation.[3] Instead, it is argued these properties and relations are interdependent, but separable, aspects of our representation of temporal change.[4]

Section 2 presents the extant case in the literature for the dependence of the B series relations on the A series properties based on Kant's temporal idealism. Granting the claim that Kant's idealism has this implication, it is argued that there remains an issue about whether the A series properties might *also* depend on the B series relations. Section 3 presents an argument for the dependence of the A series properties on the B series relations based on Kant's commitment to the incompatibility and intelligibility of change as an object of experience. This section argues that, for Kant, the intelligibility of the incompatible changing A series properties depends on B series relations. Taking this result from Section 3 together with that of Section 2, the relationship between A series properties and B series relations is one of interdependence rather than fundamentality. Section 4 provides a brief summary of the significance of Kant's position for the contemporary A series and B series debate.

2 Kant and the Dependence of the B series on the A series

This section focuses on Walker as a representative of the current stance in the Kant literature on the relationship between A series properties and B series relations.[5] This discussion is not intended to refute Walker's

[3] In "Symmetric Dependence", Elizabeth Barnes [9] argues that dependence is not always an asymmetric relation.

[4] In "The Unreality of Time", McTaggart relies on a significant claim about change in his argument for the unreality of time: time depends on change. However, he never provides a definition of change. McTaggart's argument for idealism cannot be fully analyzed without an identification of the kind of change that is required for time.

[5] In *Themes in Kant's Ethics and Metaphysics*, Melnick connects the dependence of the B series on the A series with Kant's idealism understood as constructionism:

> ... in Kant's account before and after (viz., McTaggart's B series) are not "constructible" apart from my presently being up to a certain stage in temporizing (the "cut" between the past and the present that belongs to McTaggart's A series). Since the B series exists in construction only as dependent upon and fixed in terms of the A series, McTaggart's argument, which depends in effect on an independent B series, is blocked.
>
> (Melnick 2004, p. 120 [12])

argument for the dependence of B series relations upon A series properties. Based on Kant's temporal idealism alone, it is plausible to think that B series relations are only something in relation to A series properties. However, I argue that the current discussion is incomplete because Kant's commitment to *transcendental* temporal idealism leaves open the possibility that A series properties also depend on B series relations. This possibility is further examined in Section 3.

Consider a passage from Walker that orients Kant in relation to McTaggart's distinction between the A and the B series:[6]

> For Kant time is a form of intuition. Time and space are matrices which we use to order the data given to us. As such, they are inevitably indexical, understood in terms of 'now' and 'here'. This is the "time" of McTaggart's A series, the series of events understood in terms of past, present, and future. Like McTaggart, Kant would have held that it is only through this that we can understand the B series of 'before', 'after', and dating systems. (Walker 2017, p. 209 [15])

Here Walker points out that time and space are identified with structures that order the perception of temporal and spatial things. In this way, time and space have an indexical character as always linking us to a now and a here, respectively. The divide between A series and B series positions hinges on the issue of whether there is a metaphysical difference between the present in contrast to the past and future. B series relations of being earlier than, later than, and simultaneous with do not depend on any privileged present moment, while A series properties do so depend. In this way, A series properties change, while B series relations remain. Walker's claim is that the indexical structure of inner sense implies that our cognitive grasp of B series relations depends on the experience of a privileged now—an A series property.

I agree with Walker's claim that inner sense has an indexical nature that in turn implies the dependence of the representation of B series relations upon A series properties.[7] However, reflecting on Kant's *transcendental* idealism suggests that this is not the complete story. Kant

[6] Walker, *Kant and the Philosophy of Mind: Perception, Reason, and the Self*, 209 [15].

[7] I do not have the space to fully examine Walker's argument here. Ralf Bader's "Inner Sense and Time" (2017 [7]) also provides a defense of a similar view that time as the form of inner sense has an indexical nature.

distinguishes between time and temporal relations of objects, and his idealism identifies time with that which enables us to perceive the temporal relations of objects. In other words, time is distinct from temporal relations of objects themselves. On this reading, Walker's argument focuses on the status of the B series relations of objects by emphasizing the series of temporal relations of events. Thus, Kant's *transcendental* idealism makes it requisite to also consider the structure of time itself, beyond the objects that it indexically links us to. This is especially important because the role of inner sense in making the perception of the temporal now possible contrasts with the role of outer sense in making the perception of the spatial here possible. Though they are both indexical and thus perspectival in nature, there are unique issues about awareness of the A series now that requires attention. In particular, the next section argues that the *a priori* representation of B series relations enables awareness of the A series now.

3 Kant and the Dependence of the A series on the B series

This section shows that Kant describes the formal structure of inner sense in terms of B relations in order to render the incompatibility in change intelligible. This means that insofar as the A series properties of objects are intelligible, they depend on B series relations. Taking this together with result of Section 2, it will be argued that the representation of A series properties and B series relations are cognitively interdependent. I argue that the B series relations provide the *a priori* form of inner sense that enables A series contents, but the B series relations are only temporal insofar as they are the structure of A series contents.

To begin with, understanding Kant's account of time requires attention to his methodology in developing his unique idealism. It is useful to consider that Kant's early criticism of Leibniz in the 1755 *New Elucidation* [2] is that a pre-established harmony account of causation is incompatible with change and therefore incompatible with time (1: 410). Though this critique from his early writings does not determine precisely how time and change relate to each other on his early view, it nonetheless shows that Kant takes them to be related in some way. The relationship between time and change becomes clearer in the context of Kant's 1770 *Inaugural Dissertation* [3]: Kant claims that we can

only represent change through the pure intuition of time (2: 401). The pure intuition of time is a representation that derives from the structure of the mind rather than sensation, and it relates us to a single time as a medium in which all temporal objects are oriented. In particular, the function of the pure intuition of time is to enable us to represent the irreducibly temporal incompatibility in change (2: 401). Kant's account of the relationship between time and change culminates in the 1787 B edition of the *Critique of Pure Reason*. It is here that we can see most clearly how his position on change leads him to a view that can be described as maintaining that the A series properties depend on B series relations.

As a preliminary point, it is important to note that Kant's critical position is that time presents relations rather than properties. More precisely, Kant claims that time as the structure of inner sense contains *only* relations:

> ... that which, as representation, can precede any act of thinking something is intuition and, if it contains nothing but relations, it is the form of intuition ... (B67 [1])

Time as a form of intuition is intended to explain our perception, along with our theoretical cognition, of the world. The inherently relational character of our empirical awareness suggests that the *a priori* structure of inner sense is not that of A series properties. However, this is only a negative argument to prepare for further examination of inner sense's structure.

The transcendental exposition of the concept of time is a section added to the B edition of the *Critique of Pure Reason* that describes the function of inner sense:

> Here I add further that the concept of alteration (*Veränderung*) and, with it, the concept of motion (as alteration of place), is only possible through and in the representation of time—that if this representation were not *a priori* (inner) intuition, then no concept, whatever it might be, could make comprehensible the possibility of an alteration, i.e., of a combination of contradictorily opposed predicates (e.g., a thing's being in a place and the not-being of the very same thing in the same place) in one and the same object (*Objecte*). Only in time can both contradictorily opposed determinations in

> one thing be encountered, namely successively. (B48–49, [1])

Here Kant claims that our thought of alteration depends on a pure inner intuition of time.[8] This pure intuition is a representation of succession that does not derive from sensation but rather structures the relation between our representational states. To deal with the incompatibility in alteration, Kant maintains that this change is dynamic. This means that it involves a coming into existence of a state and a coming out of existence of a state because a single thing cannot have both contradictory properties at the same time.[9] Notably, such dynamic change is often associated with proponents of the A series and thus, serves as a point of connection with Kant. However, Kant's transcendental exposition of the concept of time aims to explain how we can encounter such dynamic change, and for this task he appeals to an "*a priori* inner intuition" of succession. To better understand this, we should examine Kant's account of the pure representation of time in the context of 18^{th} century philosophy of time, to which we now turn.

Dynamic accounts of change raise the following issue for an account of time awareness. At any moment we can only perceive the present state of an object because the past states no longer exist. Thus, we require an explanation of how a mere sequence of representations can be converted into a representation of the A series now as something that changes over time. In other words, the issue concerns how change comes to be a perceptible content. Crucially, the changeable status of the temporal now is what distinguishes it from the spatial here. Augustine provides a seminal statement of this problem in Book XI of the *Confessions*. In Book XI, Augustine's solution is to say that our awareness of the now is due to it being part of a structure in which one remembers the past and expects the future. However, Augustine's solution cannot resolve the problem of how the A series now comes to be a perceptible content because it is circular; it assumes that we already have access to a

[8] Notably, the "inner" status of the intuition of time is not clearly developed in the *Inaugural Dissertation* [3], and its first explicit appearance occurs in the famous 1772 letter to Herz (10:134) [4]. Kant also raises the "fundamental question of metaphysics" in this letter, and it is widely considered to mark Kant's transition to his critical period.

[9] This position is also reflected in Kant's inference in the Analogies that " ... A would belong to a past time, and thus can no longer be an object of apprehension (*Gegenstand der Apprehension*)" (A211/B258).

change through the memory of something's being past.[10] Not only was Augustine's discussion of this problem standard background in the 18th century, but Kant also quotes Book XI of the *Confessions* in his writings on time.[11]

Kant's appeal to a *pure* intuition of time resolves the problem of how the changing now comes to be a perceptible content. The now serves as the ever-changing boundary of the past. But if the past states of an object no longer exist in the current moment, then the representation of succession does not derive from sensation. As a result, we need an *a priori* representation of succession if change is to become available as a perceptible content. In other words, rather than a sensation of succession there is a successive structure of the mind that enables the perception of successive states. This pure succession cannot be the representation of A series properties on pain of circularity. Instead, this *a priori* representation of unchanging B relations of succession is what enables the perception of the A series now. Thus, the *a priori* representation of B series relations makes the incompatibility in change intelligible in the sense that it makes dynamic change available to consciousness and, in turn, enables the thought of change.

Let us conclude by returning to Walker's claim that B series relations cognitively depend on A series properties. On Walker's view, Kant's temporal idealism is the position that inner sense has an indexical structure that picks out a privileged now. On one hand, the indexical status of time accounts for the way in which our time awareness is perspectival in its ordering, and thus emphasizes the privileged A series now. On the other hand, the purpose of the *a priori* representation of B series relations is to enable our awareness of dynamic A series contents. In this way, the structure of our awareness of A series contents is inextricably tied to our representation of B series relations. However, the *a priori* representation of B series succession would be empty without a relation to its A series contents. Given this, neither is to be preferred to the other. On Kant's view, B series relations and A series properties are separable and mutually supporting as the form and content of our representation of temporal change.

[10] Adrian Bardon makes a related Kantian point that Augustine's account cannot answer the question of the origin of our temporal representation. See Bardon, *A Brief History of the Philosophy of Time*, 26 [8].

[11] In his 1762 *Inquiry* [6], Kant cites a well-known quote from book XI: "What then is time? Provided that no one asks me, I know" (2: 284).

4 Conclusion

Kant's philosophical writings reveal a longstanding commitment to account for change, which culminates in the B edition of the *Critique of Pure Reason*. I have argued that Kant's account of change leads to a position upon which neither A series properties nor B series relations are more fundamental due to Kant's position that change is both intelligible and involves incompatibility. Though Kant's position on time is tied up with his idealism, reflection on his argumentative strategy provides a methodological insight that is useful for understanding contemporary debates. We might approach the A series / B series debate by re-examining the considerations that ground the perceived opposition between these positions. The contemporary proponent of the A series emphasizes that A series properties are changeable, while B series relations are static. In light of this, we might first consider our preferred account of change and then determine whether A series properties and B series relations might play complementary roles in accounting for change.

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Persistence reconsidered: Beyond the endurance / perdurance distinction

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Abstract

In this paper, I will argue that we need to consider the 'change-makers' if we want to provide a comprehensive theory of persistence. The classical theories of persistence, endurantism and perdurantism in all their flavours, are content with avoiding the looming contradiction in the context of Leibniz's Law. They do not account for *how* change is brought about. I argue that this is not sufficient to constitute a theory of persistence and I will introduce produrantism as a new access towards a comprehensive approach.

Keywords: Persistence, Produrantism, Endurantism, Perdurantism, Dispositions, Change

1 Introduction

The problem of persistence is one of the oldest problems in philosophy. It stems from a very common fact, namely that material objects change. This is so common place that it is hard to find something which is not

[1]I am very grateful to Anna Behrendt, Elke Brendel, Cord Friebe, Sascha Hilgert, Timo Weiß, and the anonymous referee for useful comments on the draft of this paper.

an example of change.[2] The *problem* with this is that, although changing, the objects stay the same. In a first approximation the problem of persistence, thus, is the attempted reconciliation of identity and difference, or to be more precise the reconciliation of numerical identity with qualitative difference.

It is not so much a question about the specific persistence conditions of specific things or kinds of things, but rather a question about the conditions of persistence *per se*. It may be that living beings, for example, need to exchange matter (metabolism) to persist. If so, this then constitutes a special challenge for theories of persistence of living beings and some even argue that living beings form a distinct ontological kind, because of their persistence conditions [28]. But this is not the general problem of persistence, which asks 'How is change *simpliciter* possible?'.

Now, of course, change and persistence are not the same thing, but they are closely related. Not only because some kinds of things need to change in order to persist, as just was mentioned, but rather because virtually everything changes during its lifetime. Persistence just is existence through time, but *de facto* this calls for a theory of change, as the persisting thing will most likely change during its existence. Hence, I take this to be the common ground from which every explication of persistence starts: material objects persist through time, although they change. We need a theory of persistence which is compatible with change. Or better yet: one which mirrors the close conceptual connection between change and persistence.

The paper proceeds as follows. In section 2, I will explicate the concept of change. Building on this, I will review the contemporary accounts of persistence in section 3. These fall broadly into two camps – endurantistic and perdurantistic theories – which can be spelled out in a quite diverse fashion. Nevertheless, in section 4, I claim that all theses accounts have one thing in common. They focus solely on not being contradictory. None of them actually provides a theory of how change is brought about. I will sketch produrantism as an alternative conception, which takes the 'change-makers' into account to arrive at a comprehensive approach to persistence. Finally, section 5 concludes.

[2] War may be an exception to this claim. According to [15] war never changes.

2 The concept of change re-evaluated

A theory of persistence needs to be change-friendly, and thus I will take a closer look at the concept of change in this section. According to the classical account, '[c]hange needs identity as well as difference' [25, p. 89]. It is initially plausible that both criteria are necessary for change and that they are jointly sufficient. Change needs to be differentiated from exchange, and identity is supposed to be the differentiating criterion. It is ontologically a rather different matter, whether my girlfriend dyes her hair red, or whether I kiss her ginger twin sister.

Also, the role that difference plays for the concept of change seems to be rather straightforward. It seems that something needs to *change*, in order for there to be a phenomenon of change in the first place. If a ball stays blue, there is no change, and so change needs to be differentiated from stability. Here a first caveat is in order: the properties involved in the change need to be incompatible.[3]

To sum up the pre-theoretical intuitions: in a case of change one and the same object exemplifies incompatible properties (in the same way) at different times.[4] However, this straightforward characterisation of change is in tension with a plausible principle, called[5] Leibniz's Law: $\forall x \forall y \forall P \forall Q(x = y \rightarrow (P(x) \leftrightarrow Q(x)))$. Leibniz's Law claims that if two objects are identical, then they share all their properties. Now, in the case of change, we have an identical object and two incompatible properties, which leads to a contradiction.

In the next section, I will review the most common attempts in the contemporary debate about persistence, to avoid contradictions in the context of Leibniz's Law. Note, however, that I take the problem of persistence **not** to be the problem of change. I hold change to be a subspecies of persistence, because stability is equally explanation-worthy as change even if it may not lead to a contradiction. My diagnosis for the focus on change is that the contemporary debate about persistence

[3] There are different ways of spelling this out. Aristotle claims in the Categories [2] that predicates have a genus, and anything can only fall under one predicate of a specific genus (at a time and regarding the same aspect). W. E. Johnson [17] speaks of determinables and determinates to capture the same core idea. A technically more refined variant of this can be found in Arthur Prior's works [27].

[4] The specification 'in the same way' is important since, it is not a change if someone 'is crooked according to the Times' and 'honest according to the News' [21, p. 204].

[5] I do not claim that Leibniz has actually held the principle in this way. The literature nevertheless refers to it as 'Leibniz's Law', and I stick to this convention.

accepts that the avoidance of the contradiction is sufficient for a theory of persistence. As will be become clear in section 4, I do not share this commitment.

3 Contemporary theories of persistence

In this section, I will discuss the most prominent contemporary theories of persistence.[6] These fall into two camps: perdurantistic and endurantistic theories. Roughly, perdurantists believe that objects are four-dimensional wholes, whose temporal parts exemplify the ordinary properties. Contrary to this endurantists stick to the common belief that objects are three-dimensional. Thus, enduring objects are multi-located in space-time, being wholly present [8] at each of their locations.

The debate about persistence is nowadays standardly held assuming eternalism.[7] Eternalism is only sometimes explicitly assumed (see e. g. [1, p. 11])) but virtually all positions which are discussed later implicitly presuppose eternalism. An indicator of this is that the very notion of 'mulit-location' is only sensible given eternalism. Although personally I believe that the opposing view, presentism, not only provides a viable account of the nature of time but also a solution to the problem of temporary intrinsics, I will follow the contemporary debate in presupposing eternalism for the sake of this paper. Note, however, that produrantism might constitute a way of transcending the eternalist limitation.

As for the remainder of this section, in subsection 3, I will present theories from the perdurantistic camp, and in subsection 3, I will turn to alleged solutions to the problem of persistence from the endurantistic camp. Then, in subsection 3, I will take a step back and consider the general set up of the theories. It turns out, that they all have something in common, namely they all are concerned with sidestepping the looming contradiction in the context of Leibniz's Law. The question of *how* change is brought about is not covered at all. In the next section, section 4, I will then sketch an alternative account of persistence which includes

[6] For an overview of the debate about persistence and its location within the philosophy of time see [11].

[7] Eternalism and presentism are accounts of the nature of time. Presentists think that only the present moment exists or is real, whereas eternalists believe that all of (space-)time exists on a par.

the change-makers, i. e. the entities which bring about the changes in the world.

PERDURANTISTIC ACCOUNTS

Perdurantists take it that at each moment there exists but a temporal part of a larger four-dimensional object. This object has different temporal parts at different times, and these temporal parts in turn can have different properties. Take someone who stands up and thus changes her shape from bent to straight. It is a different temporal part which has the intrinsic property of being bent than the temporal part which is straight, following the perdurantist. It is unproblematic for different objects to have incompatible properties. By taking temporal parts to be the primary property bearers, perdurantism avoids the looming contradiction in the context of Leibniz's Law. The temporal part which is bent just is not identical to the temporal part which is straight. Hence, the perdurantist solves the problem of persistence by distinguishing the primary property bearers (the three-dimensional temporal parts) from the persisting object (the four-dimensional whole).

There is a version of perdurantism, called **exdurantism** [30, p. 84], which takes the three-dimensional bearers of ordinary properties to be temporal stages rather then temporal parts [3, p. 91]. In our example, one of the temporal stages is bent and another one is straight. The two stages involved are not parts of a persisting four-dimensional whole, following the exdurantist, but are related by the counterpart relation.[8]

ENDURANTISTIC ACCOUNTS

Endurantism holds on to the everyday intuition that objects are three-dimensional. Endurantistic objects persist by being multi-located in space time [23, p. 2]. There are several ways an endurantist could try to avoid the contradiction in the context of Leibniz's Law. The first way would be to put a time-index onto the properties. This view is often called **indexicalism** [32]. The persisting object, o, is bent_{t1} and straight_{t2}. As it is neither bent simpliciter nor straight simpliciter, no

[8] Exdurantism, hence, adopts the this-worldly analog of Lewis's account of modality. According to Lewis, there is no trans-world identity, as Kripke [19, p. 45] would have it, but rather there are modal counterparts in other worlds.

contradiction arises. Being bent$_{t1}$ would only be incompatible with being straight$_{t1}$.

The problem with indexicalism becomes evident when one considers a case of stability. Take a red ball which stays red. According to the indexicalist this ball always exemplifies a different property: red$_{t1}$, red$_{t2}$, red$_{t3}$ and so on [13, p. 130]. So, although indexicalism avoids the contradiction in the context of Leibniz's Law and can distinguish between change and exchange, it is often discarded.

Another possibility for the endurantist is to time-index the copula [18, p. 129], call this **copularism**, or add an temporal adverb [14], call this **adverbialism**. Often the term adverbialism is used as an umbrella term for both versions, but I prefer to have the conceptual resources to distinguish between them. Adverbialism and copularism are considered the strongest variants of endurantism. The copularistic solution can be depicted as: o is$_{t1}$ B and o is$_{t2}$ S; and adverbialism as: o is t1-ly B and o is t2-ly S.

David Lewis provides yet another version of endurantism. Call this alleged solution to the problem of persistence **relationalism** [1, p. 19]. According to the relationalist, bent and straight are disguised relations [21, p. 204]. o stands in the relation of straightness to one space-time-point and in the relation of bentness to another space-time-point.[9]

There are two endurantistic accounts in the vicinity of relationalism which respect the intuition that ordinary properties are not relations. One way would be to time-index the relation of property-exemplification; the other way would be to take a three-place relation of property-exemplification. Let us call these views in turn **exemplificationism**$_{tn}$ and **exemplificationism**^{3}.[10] According to exemplificationism$_{tn}$ o stands in one relation of property-exemplification to the property bent and in another to the property straight. But exemplificationism$_{tn}$ can be attacked on a similar ground as indexicalism. An object which stays red would always stand in a different relation to the property red.

However, exemplificationism^3 does not fall prey to this objection. In our example, o stands in the relation E^3 to bent and t1: $E^3(o, b, t1)$; and also to straight and t2: $E^3(o, s, t2)$. It is the same relation which re-

[9]Note that although Lewis presents this version of endurantism, he himself rejects relationalism, because for him it is evident that ordinary properties are not relations.

[10]One could formulate both versions in second order logic as one of the relata is a property, here B and S, or one could use a singular term denoting a universal, here b and s. I follow Uwe Meixner [24, p. 95], who prefers the second variant.

lates objects, properties and times. On top of that, this view accepts that properties are not relations, as Lewis would like to have it, and in the case of change it is numerically the same object in both relations. Thus, exemplificationism^3 can account for continuity and can differentiate between change and exchange. Exemplificationism^3 constitutes a strong variant of endurantism, yet it is often overlooked in the debate.

TAKING STOCK

Let us now consider these theories of persistence *en pack*. Remember that Leibniz's Law poses a threat to accounts of persistence. Apparently, an object that persists and changes exemplifies incompatible properties. So, if the same object has incompatible properties in the same way this, together with Leibniz's Law, leads to a contradiction. The different accounts of persistence present different ways of avoiding this contradiction. They all deny that it is the same object which has the incompatible properties in the same way. They disagree on how to disagree with this statement. Classical perdurantists and exdurantists hold that it is not the same object; indexicalists think the properties are not incompatible; according to relationalism there are not even (one-place) properties involved; while copularism, adverbialism, exemplificationism$_{tn}$ and exemplificationism^3 all temper with the ways the properties are had.

I will call the set of classical perdurantism, exdurantism, indexicalism, relationalism, copularism, adverbialism, exemplificationism$_{tn}$ and exemplificationism^3 the 'standard theories of persistence'. All of these strategies are sufficient to avoid the contradiction, so much is true, but this is not enough to capture change. As we have seen, change consists of identity and difference. I prefer to speak of continuity rather than identity.[11] The standard theories constitute ways of supplying difference without contradiction, but also an account of continuity is needed.

Classical perdurantism ensures continuity via the parthood relation. If two temporal parts are parts of the same four-dimensional object, a persistence phenomenon is occurring. According to Ted Sider, perdurantistic persistence is a case of strict identity [30, p. 54]. Understood

[11]The term 'continuity' is more neutral than 'identity'. There are theories of persistence that deny cross-temporal identity. Exdurantism, for example, does so explicitly. It would be unfair to exclude exdurantism *per definitionem*, so I avoid to demand 'identity' for change.

like this, multi-location is not a difference-maker between endurantistic and perdurantistic accounts of persistence. Both claim that persisting objects exist at every moment of their history and thus are multi-located. Temporal mereology, via the parthood relation, tells us which temporal parts form a four-dimensional whole, which itself persists through time by multi-location. The other variant of perdurantism, exdurantism, connects the different temporal stages of one persistence phenomenon via the counterpart relation. Exdurantists deny trans-temporal identity, and hence strict identity over time cannot be the continuation-maker for them. It is *prima facie* the counterpart-relation that differentiates change from exchange for the exdurantist and it is only this.

All endurantistic accounts of persistence do not fiddle with the notion of objects. For all of these accounts, objects are three-dimensional and thus persisting objects are multi-located in space-time. Just as our everyday intuition tells us. According to all variants of endurantism, strict identity is the continuity-maker.

There is, thus, a way to account for continuity for all the standard theories of persistence. But this is virtually never mentioned. The different standard theories are only presented as to how they avoid the looming contradiction in the context of Leibniz's Law. It is then not bothered to spell out the full account of change. My diagnosis for this is that it is considered common ground in the debate about persistence that only the requirement 'difference' is problematic, because only it may lead to a contradiction. An indicator for this is that the debate focuses solely on avoiding the contradiction. Another indicator for this is that there are no hybrid theories. It is ontologically possible that, say, properties are relations and objects have temporal parts. This relationalism-perdurantism hybrid account avoids the contradiction for sure. It only seems superfluous if avoiding the contradiction is the sole task of an account of persistence. This can be had 'cheaper', i. e. by adopting either only relationalism or only perdurantism. Hence the contemporary debate about persistence focuses solely on spelling out difference without succumbing to Leibniz's Law.

This claim is backed up by another alleged solution, which we have not covered so far. One could argue that Leibniz's Law is only concerned with synchronic identity and, as it was never intended to capture diachronic identity, cannot be applied to persistence phenomena. Now, although dropping Leibniz's Law avoids the contradiction, this

solution is not satisfactory. Persistence is still mysterious. It is hard to conceptualize identity and difference together and the contradiction in the context of Leibniz's Law is but a symptom of this underlying conceptual challenge. And this is why just avoiding the contradiction is not sufficient to give an account of change and persistence.

So, I claim that there is more to change than contradiction-freeness. But I also hold that there is more to persistence than change, as stability is as much explanation-worthy as change. If I am right with this assessment, then the problem of temporary intrinsics is a sub-problem of the problem of change which itself is a sub-problem of the problem of persistence.

On top of that changes do not just occur. Personally, I believe that changes are *brought about*, and I will have more to say about this in the next section. But no matter your conviction, changes have to be accounted for in some way or other. The contemporary debate about persistence takes it for granted that there are changes in the world and, of course, I do not argue with this claim; I merely ask how: How do these changes come about? I just cannot see how one can ignore this question when trying to give a comprehensive account or persistence. In the next section, I will present one specific way answering this question and sketch a corresponding account of persistence.

4 Beyond the endurance / perdurance distinction

In this section, I will introduce *produrantism*, my favourite account of persistence. 'Produrantism' is a term of art that I have invented. It is inspired by the terms 'endurantism' and 'perdurantism', whereat the 'pro' stands for 'process'. I do not claim that produrantism is the only or best way to account for persistence; but it is a more comprehensive account of persistence than the standard theories. I believe that dispositions existenitally bring about the changes in the world. So, subsection 4 is concerned with introducing dispositions. I take the manifestations of dispositions to be processes.[12] Processes are time-extended entities and thus provide the link between dispositions and persistence. I call the resulting account of persistence produrantism. Subsection 4, then

[12]I have argued for my favourite account of dispositions at length. The interested reader is referred to [12]. In chapter 4, I argue *in extenso* why we need to understand the manifestations of dispositions as processes.

sketches how produrantism solves the problem of persistence.

CHANGE-MAKERS

Standardly, dispositions are understood as properties that need not be manifest [7]. Take the well known example of fragility. A glass cup is fragile. If it is struck with a hammer, it will break. Before the strike it is not broken, i.e. the fragility is not manifest. There are several stimulus conditions – striking it with an hammer, throwing it to the ground and so on – which may all lead to its breaking.

The current debate about dispositions revolves around so-called masking cases (Cross 2012 [9, p. 116]). The hardest masking cases are those where there is time gap δt between the occurrence of the stimulus and the manifestation (Schrenk 2010 [29, p. 729]). Take, for example, the ingestion of a deadly poison at time t_1, followed by the administering of the corresponding antidote at t_2 (Bird 1998 [5, p. 228]).

There seems to be a structural reason why these kinds of masking cases are so notorious.[13] Virtually everybody in the debate about dispositions thinks about stimulus and manifestation as events, be that implicitly or explicitly, and following Hume, 'all events seem entirely loose and separate.' (Hume 1748 [16, p. 111]). Now, if the stimulus and the manifestation are separate events, there is, in principle, a possibility of interference. And as something can come in between the stimulus and the manifestation, the manifestation can be prevented.

In linguistics, this phenomenon is well discussed in the context of the so-called imperfective paradox (Dowty 1977 [10]). From 's was walking' we can conclude that 's has walked', but in contrast, from 's was walking to the university' we cannot conclude that 's has walked to the university'. No matter how short the time that s was actually walking, this is enough to make it true that s has walked, whereas no matter how far s already came, as long as she has not reached her destination, there is in principle the possibility of interference (Thompson 2008 [31, p. 126]). We can never conclude that s has actually walked to the university while her action is still ongoing (the imperfective 'is walking'); we could conclude that only if she already reached the university, but then she is not walking any more.[14]

[13] I have argued elsewhere in much greater detail for this claim. See (Fischer 2017 [12, Ch. 4]).

[14] This observations go back to joint work with Niels van Miltenburg (2015 [26, ch. 6]).

I think that we can handle the masking cases if we consider the manifestations of dispositions as processes. This strategy attacks the 'loose' part and not the 'separate' part of Hume's dictum. 'Loose' and 'separate' are two different properties of events, and thus there are basically two strategies for building an ontology which exceeds the humean toolbox.[15] I propose that the manifestation of a disposition is an ongoing process, which starts with the stimulus, rather than stimulus and manifestation being two separate events.

The process-understanding of manifestations solves the addressed masking problem. With the ingestion of the poison, a poisoning process starts. This can lead to death or it can be stopped by administering the corresponding antidote. Even if the antidote is administered very early, there was poisoning going on. So, in a nutshell, process ontology dissolves the masking problem by differentiating between a manifestation process and its end result. While the end result (death in our example) can be prevented, it cannot be prevented that the process (poisoning) occurs if the right trigger occurs.[16]

This short overview already reveals that temporal aspects play a crucial role for understanding dispositions. Processes are essentially persisting entities, and this indicates that also from the viewpoint of the debate about dispositions a comprehensive account, including persistence, makes sense, if not is required. Thus, in the next section, I will sketch how an account of persistence including processes could look like.

PRODURANTISM

In this section, finally, produrantism will be introduced. I will also describe how the produrantistic account avoids the contradiction in the context of Leibniz's Law. But contradiction-freeness comes out as a corollary for produrantism, it is not its *raison d'etre*. However, a full account of produrance is beyond the scope of this paper. Rather, I want to show that it is possible to include change-makers into the account of persistence.

[15] I do not claim that Hume himself has a restricted ontology, excluding all entities which are not loose and separate. The neo-humean philosophers, championed by David Lewis, however have explicitly done so [22, p. ix].

[16] Of course also a lot can be said about what the right trigger is. Here is not the place for this, however. I can, once again, only refer to [12], where this is covered in length.

The produrantistic account consists of three 'levels'. First, there are the dispositions whose manifestations are the processes on the second level. Finally there are the ordinary objects which are the primary property bearers. Thus, produrantism avoids the looming contradiction by distinguishing between the persisting entity and the primary property bearers. In figure 1, a change from red to blue is depicted. The property bearer of the redness, a_1, is not identical to the blue entity, a_2.

Jeffery Brower [6] has revealed that perdurantism belongs to a group of structurally identical solutions.[17] Structurally it is enough to avoid the contradiction if the persisting entity and primary property bearers are not identical. To arrive at a theory of persistence, this structure needs to be complemented with an account of the nature of the entities involved and the relation between them. For classical perdurantism, the primary property bearers are temporal parts while the persisting entity is the four-dimensional whole. Obviously, the relation between them is the parthood relation.

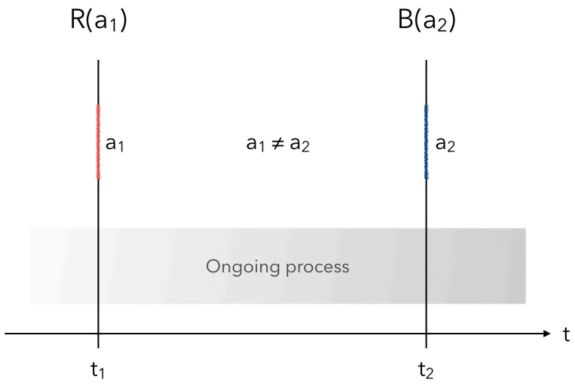

Figure 1: *Produrance*

In the case of produrantism, processes are the persisting entities, while abstractions are the primary property bearers. This goes back to an idea of Henri Bergson [4]. Bergson has worked extensively on

[17] Brower's own account, 'Aristotelian Endurantism' as he calls it, also belongs to this group. We do not have the space to go into his account here, but the name already gives it away that it belongs to the endurantistic camp.

the relation between the underlying process and the objects we ascribe properties to. 'For Bergson, there is always a priority of movement over the things that move; the thing that moves is an abstraction from the movement.' [20, sec. 2]. We cannot go into this here and so this short sketch of produrantism will have to do. Although sketchy, it is sufficient to see that produrance, is able to *account* for stability phenomena in the same way as it accounts for change phenomena. The abstractions, a_1 and a_2, ontologically depend on the underlying process, no matter whether they exemplify incompatible (change) or the same (stability) properties.

5 Conclusion

In this paper, I have argued that the contemporary debate about persistence focuses solely on avoiding the looming contradiction in the context of Leibniz's Law. This one-sided approach is the reason why the debate got stuck, I believe. An account of change needs to include continuity as well as difference, and an account of persistence needs to cover stability as well as change. All the standard theories of persistence – classical perdurantism, exdurantists, indexicalism, relationalism, copularism, adverbialism, exemplificationism$_{tn}$ and exemplificationism^3 – are content with spelling out difference in a contradiction-free manner. They can be amended to include continuity, but none of them accounts for how change is brought about or how things persist through time. I have introduced produrantism as a counter-project. Produrantism includes dispositions as the change-makers into the picture. Their manifestations are processes, which themselves are the basis for persistence. Produrantism avoids the contradiction by differentiating between the primary property bearers and the persisting entities, but is not reducible to this job.

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The Dynamic Present

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Abstract

The so called "at-at" theory of change and motion states that there is nothing more to change than objects' possessing different properties at different times, and nothing more to motion than their being in different positions at different times. In this theory the history of the world is reduced to a succession of individually static world-states which take it in turns to be present. In most versions of the theory, in order to accommodate continuity of change and motion, it is assumed that the present times at which such static world-states hold are instants. The picture of reality thus presented favours an ontology in which the first-class entities are substances, or objects, which act as the bearers of the static properties and positions whose different values at different instants constitute the changes and motions that those entities undergo. A persistent, if minority, strain in the history of philosophy, however, has held that the first-class inhabitants of the ontology should be processes rather than objects. This idea raises problems for the traditional instant-based model of time, since processes, being inherently temporally extended, can only exist over intervals, not at instants. This paper draws on the ideas of such philosophers as Whitehead, James, and Bergson to explore the ramifications of the idea that the present should be treated as an interval whose contents are inherently dynamic in nature, the dynamic present of the title.

Keywords: Process, Change, Instants and intervals, The specious present, Object image-schema

§1. For some years now a number of theoretical biologists and philosophers of biology have been advocating a position which might be labelled *bio-processism*, the central tenet of which is that living organisms

are best understood, not as Aristotelian substances, but as processes — or more exactly, as highly coordinated systems of processes. In other words, living systems are fundamentally processual in nature.[1] This point of view seems to follow naturally from the observation that every living organism, throughout its existence, is engaged in a constant interchange of matter and energy with its environment, and that this activity is sustained by internal metabolic and other processes that constitute the life of the organism — if these processes stop, the organism dies and becomes just a lump of inert matter.

At any time, a living body consists of a certain quantity of matter, organised in a particular and highly intricate way; but over time, there is a wholesale turnaround of the matter, while preserving the same organisation. That it is a *living* body depends essentially on this process by which it is constantly rebuilding itself; in the absence of the process, the matter may remain, but the body is no longer living. For this reason the body, *qua* living, is better identified with the process than with the matter.[2]

§2. It is not just in biology, however, that we find "objects" that appear to be processual in nature. In geography we find a range of phenomena which, while we may think of them as objects, may be better understood as processes. Examples include waterfalls, rivers, ocean currents, hurricanes, and tornadoes. All these phenomena may be said to present both a "thing"-like aspect and a "process"-like aspect.[3] In its thing-like aspect, an example of such a phenomenon has, at any time, a more or less definite shape, size, position, and material constitution, and these attributes tend to vary over time in a smooth and continuous fashion. They may be said to move and to change shape: in the case of rivers and waterfalls these changes are very slow — it usually takes many years for the course of a river to change appreciably — but with hurricanes and tornadoes they happen quickly, on a timescale of hours and days rather than years and centuries. The changes in material constitution, on the other hand, tend to be rapid: which is why Heraclitus is sup-

[1] See for example [17].

[2] That living bodies continuously rebuild themselves was pointed out by Schoenheimer [44]. In philosophy a prominent exponent of the same idea was Jonas [32].

[3] Hence I have elsewhere described them as *dual-aspect phenomena*, and suggested that such phenomena present a challenge for the traditional distinction between substances (continuants) and processes (occurrents). See [18, 19].

posed to have said that one cannot step into the same river twice.[4] If the river is identified with the water, then it is indeed true that each time you step into it, it is a different river: but this is not how we individuate rivers. The Thames that I see when I visit London is the same river as the Thames that I knew when I lived there as a child, but the water is quite different; so the river is not the water. Is it the channel through which the water is flowing? One might say this, and in the case of seasonal rivers which only flow at certain times of year (or in certain years) this may seem to be a reasonable position. But what makes a channel a river is the fact that at least sometimes there is water flowing along it. So a river might be said to be a channel associated with a flowing process — or is it rather a flowing process associated with a channel?

In the case of an ocean current (the Gulf Stream, say) all we have is the flowing process: there is no channel. If the process stops, the current ceases to exist. Hurricanes and tornadoes are similar in this respect. These are clearly processual entities, even though, viewed in a certain way, they may present themselves as objects with identities (we do, after all, give them *names*).

§3. So for living organisms and certain geographical entities, which traditionally would be classed as continuants, there seems to be a good case for saying that in some sense they are "really" processes. Some philosophers have taken this a step further and maintain that *everything* that we would normally take to be an object is in fact a process. This idea gains some support from fundamental physics, where particles are replaced by dynamic fields of various kinds.

Such radical processism has attracted adherents throughout the history of western philosophy, at least as far back as Heraclitus.[5] It has also featured in eastern philosophy, in particular in Buddhist philosophy, where, as I understand it, all of reality is regarded as fundamentally processual in nature.

§4. It was suggested above that the continuant/occurrent distinction is less clear than it has often been presented; and many traditional sub-

[4] This is Plutarch's version: "it is not possible to step twice into the same river, according to Heraclitus"; but the surviving fragment from Heraclitus touching on this matter says "On those who enter the same rivers, ever different waters flow" [6].

[5] An eloquent exponent of such a view is Rescher (2000 [39]). For a general survey, see [45].

stance ontologists can be expected to baulk at this suggestion. It is, they will say, a category mistake to conflate, say, an individual with that individual's life.[6] And this is certainly true if by the life of an individual is meant an extended event, from birth to death, considered as a unitary whole. But if on the other hand "life" refers to the *process of living*, considered as something dynamic and ongoing, then it is much less clear that there is a serious categorial error in identifying the living organism with its life processes.

§5. Such considerations as this have led a number of philosophers[7] to propose a view of processes according to which processes are, if not actually continuants, at least continuant-like in certain important respects. Most notably, there is a way in which a process can be said to exist as a whole at each time that it is in operation; at each such time it has certain qualities, and these qualities may change as the process develops. Thus a person's walking process may become faster or slower, or change direction, and these changes are changes in the process rather than in the person — a person does not *have* a direction, only an orientation, which is a different thing entirely.

On this understanding of the term "process" there are processes going on *now*. Events, by contrast, can only be said to be going on in the derivative sense that some processes that are constitutive of the events are going on. An event, on this view, is a temporally extended whole, which cannot meaningfully be said to undergo change, being rather a kind of aggregation of changes that take place over its duration [22]. As documented elsewhere [24], the terms "process" and "event" have very different meanings in everyday life, and it is unfortunate that amongst philosophers and ontologists there has been considerable confusion between them.

It should be noted that some formal ontologies do not recognise this understanding of process as something present, ongoing, and changeable. In Basic Formal Ontology (BFO) [4], for example, the term "process" refers to a four-dimensional, spatio-temporally extended entity, after the fashion of perdurantism, something more like an event as this term was introduced above. This is not what is meant by a process here,

[6] Compare David Wiggins's response to Broad's remark that there is no important categorical difference between a flash of lightning and the cliffs of Dover [54, p.25, n.12].

[7] For example Stout (1997, 2003 [48, 49]), Galton (2006, 2006, 2008, 2009 [20, 21, 22, 24]).

and it is essential, for a proper understanding of the arguments presented in this paper, not to confuse these two senses of the term.

§6. Whether or not substances are reduced to or identified with processes, so long as processes are accepted as first-class elements of reality, the traditional "at-at" theory of change will have to be abandoned. According to this theory, change is nothing other than different states holding at different times: *at* time t_1, state ϕ holds, and *at* time t_2, $\neg\phi$ holds. If ϕ is an object's being in a particular position, then the change described is motion of that object.[8] The at-at theory is a natural adjunct to the substance ontology. If substances are the only first-class entities, and hence ontologically prior to processes, then all change and movement must be explained in terms of the possession by a substance of different static properties or positions at different times. As Bergson puts it, this is to treat movement "as though it were made of immobilities" [7, Ch.5].[9]

§7. Now, on the at-at theory, what are the "times" at which the static configurations ("immobilities") are supposed to hold? If change and motion are to be continuous, as experience for the most part suggests they are, then the times must be indivisible instants, since if they are intervals, then at the meeting point of two consecutive intervals over which different static configurations hold, there must be a discontinuity.[10] These instants must form a *continuum*, and the only account we have of a continuum of instants that is anything like coherent is the mathematical model using the ordered set of real numbers $\mathbb{R}$. And in-

[8] As an account of motion, the at-at theory can be traced to William of Ockham. A classic statement is by Bertrand Russell: "Motion consists merely in the occupation of different places at different times" [42].

[9] Compare also James (1909) [30, Lecture 6]: "Whatever motion really may be, it surely is not static; but the definition we have gained [in the at-at theory] is of the absolutely static. It gives a set of one-to-one relations between space-points and time-points, which relations themselves are as fixed as the points are. It gives *positions* ad infinitum, but how the body gets from one position to another it omits to mention. The body gets there by moving, of course; but the conceived positions, however numerously multiplied, contain no element of movement, so Zeno, using nothing but them in his discussion, has no alternative but to say that our intellect repudiates motion as a non-reality."

[10] This applies on the assumption that there is a lower limit to the duration of the intervals. There are alternative possibilities (e.g., the "middle-third" construction), but none of them appears to give a credible model of how reality might be.

deed, in view of our use of numbers to measure time durations, and the mathematical theories needed to underpin the widespread use of the differential and integral calculus in the natural sciences, this seems to be a natural choice.[11]

If $\mathbb{R}$ is understood as a given completed totality, then by Cantor's argument its members must be non-denumerably infinite. Ontologically (as an account of physical reality), this must be regarded as highly problematic, most notably because (a) it requires us to believe in the existence of actual (as opposed to potential) infinities in the physical world; and (b) almost all the elements of $\mathbb{R}$ are in principle inaccessible and unknowable.[12]

§8. Earlier, it was claimed that there are processes going on *now* — in other words, at the immediately present time. How, then, are we to characterise the present? On the at-at theory, the present time is an instant, the "knife edge" separating the past from the future. Is this characterisation tenable?

An important, and surely obvious, constraint on any model of time, is that every part of the past was once present — or more exactly (since the parts of the past include durations that were never present all at once), *the past consists entirely of former presents*. So whatever the present is like, it must be such that the past can be constructed, as it were, out of parts which are of a similar nature to the present. If the present is an instant, then the past must be constructed out of instants. Something like this seems to be implied by the use of $\mathbb{R}$ to represent time, at least so long as one makes no distinction between time itself and the set of all time instants. Aristotle, although the modern conception of the real number line was not yet available to him, was acutely aware of the issue here: using the term "now" to refer to an instant, he states that "the

[11] There have, however, been a number of attempts to secure all the advantages of the classical point-based continuum using an ontology of intervals (in time) or regions (in space) only: see for example [16, 41, 26, 27]. These endeavours can be traced back to Whitehead's notion of *extensive abstraction*.

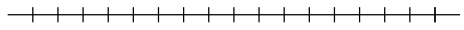
[12] A possible way out of the second difficulty is to suggest that, instead of $\mathbb{R}$ itself, which is characterised using the second-order Dedekind completeness axiom, we could make do with one of the denumerable models obtained if we replace this axiom with its first-order version (which in effect replaces quantification over arbitrary sets by quantification over sets definable within the first-order language) — for example, the real algebraic numbers, or the Turing-computable numbers. But this still does not overcome the first difficulty.

now is not a part of time, because a part measures the whole and the whole must consist of its parts; time, however, does not seem to consist of nows" (*Physics* IV 218a7).[13]

A major problem here is that, as has frequently been argued, an extended duration cannot possibly be made of extensionless instants. If the duration of an instant is zero then however many instants are piled up together, the resulting duration must still be zero. So if the past, which is extended, is made of things that were once present, then the present cannot be extensionless: it cannot be an instant as traditionally conceived.[14]

§9. In view of the foregoing, it would seem advisable to replace all talk of the "present instant" using the more natural-seeming "present moment". This might seem to be a trivial change, but consider the etymologies: "instant" means "standing in", strongly suggestive of something static; but "moment" means "movement" and therefore connotes something dynamic. The present *moment* must have room for change and movement, and therefore it must be extended. Somehow time must be composed of moments. But how?

The simplest possibility is a discrete series, like this:



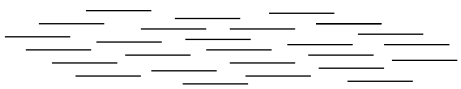
One might think that this would inevitably lead to discontinuities, as in the interval version of the at-at theory; but the reason that case led to discontinuities was that the state of the world had to be constant over each minimal interval, whereas if we are dealing with dynamic moments of time — that is, moments in which change can occur — then there is no reason why the state at the end of each interval should not exactly match the state at the start of the next. None the less, this picture seems rather unsatisfactory, since time does not seem to us to be a discrete sequence of intervals like this. Rather, each present moment seems to slip

[13]The translation is from [2].

[14]The mathematicians of the sixteenth century were well aware of this problem; to get round it, they postulated *infinitesimals*, magnitudes that are not zero, but are smaller than any magnitude measurable by a real number. This conception is clearly repugnant to anyone averse to actual infinities, for we now have a model of time comprising an actual infinitely large number of actual infinitely small quantities. All of natural philosophy rested on this shaky foundation until the rigorous formulation of the concept of limit by Cauchy and Weierstrass in the nineteenth century.

smoothly into the succeeding moments, there being no unique "next" moment to which it is exactly adjacent.

Perhaps, therefore a better picture is something like this:[15]



As a picture, this too is rather unsatisfactory, but it is at least suggestive of the idea of the present as a sort of "sliding window" that moves forward in time (or perhaps better, a static window through which time flows) which corresponds, at least in a rough and ready way, to the hard-to-articulate sense we have of the passage of time as we experience it.

One thing which is perhaps misleading in both pictures is the suggestion that the interval constituting the present moment is a well-defined temporal extent with sharp beginning and end points. Nothing in our experience seems to correspond to such sharp termini, and it may be more satisfactory to picture the intervals as "fading out" towards both the beginning and end.

§10. The picture thus painted is strongly reminiscent of the psychological notion of the "specious present". This is associated with the philosopher-psychologist William James, who did not originate it,[16] but was largely responsible for popularising it. Henri Bergson espoused a similar concept; the parallel between these two authors is clear:

James: "The specious present has ... a vaguely vanishing backward and forward fringe." / "The unit of composition of our perception of time is a *duration*, with a bow and a stern, as it were — a rearward- and a forward-looking end." [29, Ch.15]

Bergson: "Our consciousness tells us that when we speak of our present we are thinking of a certain interval of duration. What duration? It is impossible to fix it exactly, as it is something rather elusive." [7, Ch.5].

[15] This picture is similar to Michael Dummett's "fuzzy realism" [16]. Dummett also uses the term "moment" for his minimal temporal intervals.

[16] James attributed the notion to a mysterious "E. R. Clay", subsequently identified as an amateur philosopher by the name of E. R. Kelly — see [1].

In addition, both authors agree that although we *can* talk of instants, these are merely mental constructions, not corresponding to anything in reality:

James: "The literally present moment is a purely verbal supposition, not a position; the only present ever realised concretely being the 'passing moment' in which the dying rearward of time and its dawning future forever mix their lights." [30, Lect.6]

Bergson: "What precisely is the present? If it is a question of the present instant — I mean of a mathematical instant which would be to time what the mathematical point is to the line — it is clear that such an instant is a pure abstraction, an aspect of the mind: it cannot have real existence." [7, Ch.5].

Whitehead concurs:

> "There is no such thing as nature at an instant posited by sense-awareness. What sense-awareness delivers over for knowledge is nature through a period."
>
> (Whitehead [53, Ch.3])

as does Walker:

> "[U]n instant, n'est pas une expérience de base, physique ou psychologique, mais est un concept dérivé d'expériences ayant une certaine *durée* temporelle. Le caractère temporel d'une expérience doit être dépeint comme un intervalle, plutôt que comme un point, ..." (Walker 1947 [52])

It is also noteworthy that St Augustine, in his extended and justly-famous discussion of time in the *Confessions*, while finding himself led to identify the present with an instant, clearly feels some qualms about this:

> "[T]he only time that can be called present is an instant, *if we can conceive of such*, that cannot be divided even into the most minute fractions, and a point of time as small as this

> passes so rapidly from the future to the past that its duration is without length. For if its duration were prolonged, it could be divided into past and future. When it is present it has no duration." (Augustine, [5, Book XI, 15, italics mine])

§11. In earlier work (e.g., Galton (2008) [22]), I flirted with the idea of a *dynamic instant*, that is, an instant in which actual change or motion is present. Only so, it seemed, could the idea of processes as continuants gain any purchase. This idea is closely related to the question of the ontological status of instantaneous velocities and states of change, which has been the subject of considerable debate amongst philosophers.[17] The problem is that, although mathematicians can define the velocity of a moving object at an instant, using the differential calculus, this definition makes the instantaneous velocity dependent on the positions occupied by the object at times other than the instant in question, which means that it cannot be regarded as a property of the instant in question per se.

If, though, instants are abandoned, then the question of instantaneous velocity becomes a non-question: there are only average velocities over intervals. An instantaneous velocity must then be seen as an idealisation arrived at by conceiving of a limit of average velocities over an infinite sequence of ever-shorter intervals converging on an instant. It is all of a piece with the idealised nature of the instant itself, and the dynamism of the present is restored by making the present an interval as suggested.

On this view, motion and change are primitive facts, and as such are available for providing explanations for why the world is different at different times. The fact that an object is in motion at a particular time can be invoked to explain why it is in a different position immediately afterwards; whereas if being in motion were *defined*, in accordance with the at-at theory, as occupation of different positions at different times, any such explanation would collapse into a tautology.

§12. But should instants be altogether abandoned? Even if, as argued above, a temporal duration cannot be regarded as composed of nothing

[17] For a representative selection, see [51, 9, 3, 14, 35, 46].

but instants, this does not mean that we have no further use for instants. A useful point of entry here is provided by Zeno's paradoxes. In rebutting Zeno's argument that a moving object cannot reach its target because there are infinitely many other places it must visit first, Aristotle notes that "the conclusion that it is impossible to reach a limit is a result of dividing the magnitude in a certain way" (*Physics* VI 9 239b20) — that is, one divides the distance to be traversed into a sequence of ever shorter subdistances converging on the target, and assumes that the traversal of each separate subdistance is a separate motion. If one had to signal completion of each of these motions in some way, for example by stopping briefly, or raising one's hand, then it would indeed be impossible to complete the full traversal. Bergson likewise notes that Zeno's arguments "all ... involve the conviction that one can treat movements as one treats space, divide it without taking account of its articulations" [7, Ch.5].

What are these "articulations"? Bergson's view was that any motion must be indivisible. If it were divided by some point of articulation, then it would not be one motion but two. He must be thinking here of *intrinsic* articulations, such as the steps of a running process, or the individual bounces of a bouncing ball. On the other hand one can consider *extrinsic* articulations, imposed on the movement by its relation to something external, for example crossing a line. When a moving object crosses a line (a line, that is, which is actually marked in space by means of some qualitative discontinuity), there is no interruption to the movement itself (so it does not consist of two movements complete in themselves) but none the less we can divide the movement in thought into two phases — between which, however, there is no intrinsic discontinuity. Similarly, if during the course of the movement there is a flash of lightning, then again we can distinguish in thought the movement before the flash and the movement after, and we can ask, for instance, where the object was when the flash occurred (that is, through what spatial position was it then passing?).

These points of articulation, whether intrinsic or extrinsic, are provided by *qualitative discontinuities* in reality. Examples of such discontinuities include the sudden onset of some noise, the onset of motion in a body that has been at rest, the first contact of two bodies in collision, and the attainment of the highest point in the trajectory of a ball thrown vertically upwards. In reality there is no possibility of narrow-

ing down the intervals within which such events occur to zero durations, so the "instants" we obtain from them are idealised approximations; but still, they can serve their purpose in defining articulations of extended movements within which they occur. If we uphold the Aristotelian doctrine that no actual infinities exist, then only finitely many such discontinuities can occur in the course of a finite movement. That is why a movement cannot be articulated by means of an infinite series such as $\frac{1}{2}, \frac{3}{4}, \frac{7}{8}, \frac{15}{16}, \ldots$; so one cannot present the movement from 0 to 1 as composed of *first* a movement from 0 to $\frac{1}{2}$, *then* a movement from $\frac{1}{2}$ to $\frac{3}{4}$, and so on.

The conclusion here is then that we can pick out instants in time by adverting to qualitative discontinuities in what happens in time; but we cannot freely help ourselves to arbitrary collections of instants (specified by subsets of $\mathbb{R}$) which do not correspond to anything given to us in reality, as if time itself were *made* of instants.[18] This is all very Aristotelian — compare Coope [15, p.13].

§13. To such a conception of time it might be objected that it is entirely founded on the nature of subjective human experience: it is a theory of time as we experience it, not of time as it really is. In relation to the latter, it might be argued that the phenomenal success of the mathematical conception of time in the physical sciences is an indication that that conception really does capture the real nature of time. And in some sense it must do so, otherwise it simply wouldn't work; but if, as the foregoing considerations suggest, this model is a metaphysical absurdity, then this is something that calls for an explanation, rather than itself explaining the true nature of things. Wigner's famous phrase, "the unreasonable effectiveness of mathematics in the natural sciences" [55], comes to mind here.

In defence of the approach advocated here, it could be argued that in the final instance human experience is all we have to go on. We can, it is true, extend the range of our experience through technological means (microscopes and telescopes and ever more sophisticated instrumentation); and such means allow us to examine spatial and temporal extents

[18] This way of characterising instants — as picked out from the time-line by some qualitative discontinuity — is very different from the *extensive abstraction* of Whitehead, which presupposes the availability of an actual infinity of arbitrary small parts of any duration, contrary to the Aristotelian (and Bergsonian) notion of parts only existing as a result of being explicitly marked out.

that are much smaller than any accessible to the unaided human senses. But this is to widen the scope of human experience, not to replace it; and the times and spaces revealed in this way are still *extents*: there is nothing in the existence of such technological enhancements to suggest that those extents are really made of extensionless (or infinitesimal) atoms — and reason seems to tell us that they cannot be.[19]

That our understanding of the nature of time should be derived from our experience of time is fully in accord with Kant's theory by which time is the "form of inner sense" and as such, being a necessary feature of our experience, cannot be said to exist independently of our experience. Whatever feature of the world as it is in itself, independently of all experience, shows up in our experience as temporal ordering, must remain forever unknown and unknowable to us — a *noumenon* rather than a *phenomenon*.

§14. Alongside the question of the temporal extent of the present, we might also consider its spatial extent. In the light of the Special Theory of Relativity (STR), extending the notion of the present to include distant locations is problematic because STR rules out the existence of a global simultaneity relation based on the causal structure of space-time. A common response is to assert that "now" is a purely subjective notion, dependent on the spatio-temporal location and state of motion of individual observers [37, 40]. But this has had plenty of detractors.

Lango [34], Rakić [38], and Bourne [10], for example, argue for the objective existence of some temporally ordered sequence of "simultaneity surfaces" which are maximal collections of space-time points any two of which are causally unrelated (spacelike-separated). These surfaces define the sequence of objective "now"s. Since they cannot be defined purely on the basis of the causal structure, however, there seems to be no principled way of determining which of the infinitely many possible candidates for such an ordering is objectively real. For many, this objection is decisive, but Rakić counters this with the observation that the notions of past, present and future are not temporal (if by this is meant "pertaining to the time-dimension of Minkowski space") but ontological, and that STR is "only partly informative" on ontological

[19] Cf. Whitehead: "A duration retains within itself the passage of nature. There are within it antecedents and consequents which are also durations which may be the complete specious presents of quicker consciousnesses." [53, Ch.3]

matters.

There are other possibilities. Stein [47] and Čapek [13] argue that the "present" can only refer to the here and now, with minimal spatial as well as temporal extent, while the past and future comprise respectively the backward and forward directed portions of the observer's light-cone. This makes past, present and future dependent on spatio-temporal locations but not on states of motion. Another view, proposed by Godfrey-Smith [25] and partially endorsed by Hinchliff [28], identifies the present with the surface of the backward-directed light-cone; this means that we see distant galaxies as they are "now" and not, as conventional wisdom has it, as they were millions of years ago.

Once we introduce the idea of the temporally extended present, new possibilities open up. We could define the spatio-temporal extent of the present for a given observer to be the intersection of the future light-cone of the start of the observer's specious present with the past light-cone of its end. A space-time point then counts as present if a two-way exchange of signals between the observer and that point can be completed within the span of the observer's specious present. Such an exchange of signals is a prerequisite for the sense of "mutual presence" by which we may say that, for example, everyone currently living on earth is moving through time together, with a shared past, present and future.[20] If our specious present has a duration of, say, 0.1 seconds, then the spatial extent of the present will be 15,000 km in every direction from us — enough to encompass all of the earth, but not extending as far as the moon, with which no mutual communication is possible within the span of a single specious present.

§15. The picture so far presented is of a continuously evolving dynamic, extended present, a present made up of processes in the act of happening, smoothly evolving as the moments pass. Continuity is secured by the moments' forming not a discrete sequence but a densely overlapping aggregation (cf. [16]).

If processes are the ultimate reality, what of objects? According to process philosophers, they are "islands of stability" in the flux, arising when various collections of processes interact in such a way as to preserve some constancy of form. There may be many different ways in which this can happen but the key observation, if this general view

[20] For antecedents of this idea, see [11, 12].

is correct, is, as expressed by Mark Bickhard, that in a process metaphysics "change becomes the default, and it is stability, should such occur, that requires explanation" [8]. Indeed, just such a view was already expressed by Bergson, who suggests a very general form that such an explanation might take:

> "Movement is reality itself, and what we call immobility is a certain state of things analogous to that produced when two trains move at the same speed, in the same direction, on parallel tracks: each of the trains is immovable to the travellers seated in the other." (Bergson 1946 [7, Ch. 5])

The ordinary solid objects of everyday life — this table, that pebble — exemplify an extreme form of stability. They seem to us inert, quite the opposite of processual. But that is because all the processes that constitute their existence are at the submicroscopic level: the incessant interplay of atomic and subatomic motions which combine to hold the things together, to generate a focal point of solidity and changelessness in the face of all the potentially disruptive forces that conspire to pull them apart. We cannot see the processes, but we see the resulting stability well enough, which misleads us into thinking that it is the stability, and not the processes, that is fundamental.

§16. How, then, can we characterise objects in a world of processes? While the *existence* of an object may be constituted by the stable interplay of internal processes, its *significance* for us who share its world lies in the interactions of the object with the rest of the world. We come to know objects through these interactions, but must explain them through the internal processes.

This picture led to the characterisation of an object as "an *interface* between its internal and external processes: ... a point of stability in the world in virtue of which certain processes are characterised as internal, and others as external" [24]. This may be compared with the similar distinction between the "internal-constitutive" and "external-interactive" processes exhibited by cellular systems, as described in [36].

This picture may be developed further using the notion of *image schema* introduced in Cognitive Science to explain, amongst other things, how metaphors work [31, 33]. Image schemas are recurring patterns by which we mould our raw experiences into a structured understanding of the world. They operate "at a level of mental organization that falls

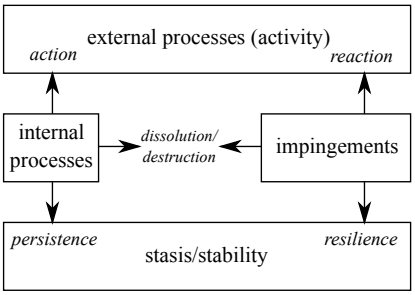


Figure 1: An OBJECT schema

between abstract propositional structures, on the one side, and particular concrete images, on the other" [31]. We may postulate an OBJECT image-schema which allows us to form object concepts in an experiential world dominated by processes. An example of such a schema is illustrated in Figure 1.[21]

The most fundamental feature we expect to find in any object is *persistence*: an object manifests a certain stability, either of matter or form. From a process-ontological perspective, this stability is at some level achieved through a balancing out of its internal processes. But objects can also undergo changes, so long as these do not disrupt their essential stability. Different types of object will tolerate different degrees of perturbation. Intrinsic changes affect the matter and form of the object itself, whereas extrinsic changes affect its relation to its environment — most obviously its position, giving motion. These changes or motions can come about either autonomously or in response to forces coming from outside (*impingements*): thus objects may exhibit both *action* and *reaction*. But because of stability, an object is able also to resist external forces, giving us *resilience*. Finally, if the balance of the internal processes cannot be maintained, perhaps as a result of external forces too strong to respond to while maintaining stability, the object may undergo *destruction*, involving the separation or dissipation of its parts.

This object-schema is specified entirely in terms of processes; if such a schema can successfully capture our notion of what it is for there to

[21] This schema was previously proposed in [23]. Compare this with the rather different OBJECT image-schemas proposed by Santibáñez [43] and Szwedek [50], which are not, or not overtly, designed to characterise objects entirely in terms of processes.

be an object, then objects must be dependent on processes. For a thoroughgoing process ontology one needs to go further than this and show that objects are dependent on *nothing but* processes; only on this basis could we claim that objects are constituted by processes, that the nature of objects is essentially processual. If the present is truly dynamic, then this conclusion seems inescapable.

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Tense and Omniscience

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Abstract

In traditional theism, God is often said to be both omniscient and timeless. Prior's insight on the impossibility for a timeless entity to know the truth of temporal propositions has given rise to an interesting debate concerning the consistency of instantiating these attributes. In the present paper we intend to clarify the current debate by proposing different logical frameworks which allow us to adequately characterize the main intuitions on this issue and by showing that the possibility of an atemporal omniscient agent strongly depends on the metaphysical assumptions we are willing to adopt.

Keywords: omniscience, static universe, dynamic universe, epistemic logic, knowledge representation

1 Introduction

In traditional theism, God is often said to possess two different attributes through statements such as 1. and 2.:

1. God is omniscient
2. God is a timeless entity

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Some scholars, call them *incompatibilists*, have argued that no entity can instantiate both these attributes, since no timeless entity can possibly know what time is it now. As Prior has it, if God is out of time, His knowledge is limited:

> God could not, on the view I am considering, know that the 1960 final examinations at Manchester are now over; for this isn't something that He or anyone could know timelessly, because it just isn't true timelessly. It's true now, but it wasn't true a year ago (I write this on August 29th, 1960) and so far as I can see all that can be said on this subject timelessly is that the finishing-date of the 1960 final examinations is an earlier one than August 29th, and this is not the thing we know when we know that those exams are over. (Prior 1962, p. 116)

Other scholars, call them *compatibilists*, are not convinced by Prior's argument and maintain that it is possible for an atemporal agent to know what time it is, and so that omniscience and timelessness can be instantiated by the same agent.

In the Compatibilism / Incompatibilism debate, both semantic issues relative to the interpretation of indexicals and metaphysical issues relative to the ontology of time are interwoven. This notwithstanding, we believe that the actual core of the debate is constituted by pure metaphysical questions concerning both the temporal structure of universe and the way in which God exists relative to time. We thus accept a specific constraint on omniscience which is reminiscent of the principle that Zagzebski (1991) introduces:

(**Omn**) In describing omniscience the perspectival aspects of the modality of knowledge are not relevant but exclusively what is known is.

On the basis of (Omn), we reject the idea that an agent can fail to be omniscient just because he is unable to know something from a certain limited perspective (e.g. that God can fail to be omniscient because He knows only that it rains in London but not that it rains *here*).

In the present paper, we aim at proposing a definition of omniscience which is consistent with this constraint and to put the Compatibilism /

Incompatibilism debate into a general framework in which the metaphysical assumptions underlying the different positions are completely explicit. In more detail, we will provide two logical systems which will allow us to adequately characterize the main intuitions at work. Within these frameworks we will actually prove (i) that in a frozen, untensed, universe God can be immutable and omniscient and (ii) that in a dynamic, tensed universe, God cannot be omniscient and immutable. Thirdly, we will put forward a new conception of the connection between human and divine knowledge which allows for all the desiderata: an immutable, eternal, omniscient God in a tensed world. In order to do that, we will introduce a final logical system where, provided some crucial conditions are accepted, it is possible to combine immutability and omniscience.

2 Basic concepts

Let x be an entity. We say that x is *temporal* if there is a time at which it is located and that it is *atemporal* or *timeless* if there is no time at which it is located. Furthermore, x is *mutable* with respect to a property if there can be a time at which it possesses the property and a time at which it does not possesses it and it is *immutable* otherwise. Finally, we say that a model of time is *untensed* if it does not admit tensed primitive properties, such as past, present, and future: the world is static and the passage of time is the outcome of some kind of cognitive illusion. On a *tensed* conception of the world, by contrast, there are tensed facts. This means that there is an objective property of being present that is dynamic, i.e. that changes from time to time.[2]

It is now possible to see what happens when we combine the concepts defined above. As to the couples atemporal/temporal and immutable/mutable, four combinations seem to be initially conceivable:

[2]Obviously, the three pairs of concepts can be specified in detail. However, here, it is sufficient this level of analysis; we will provide a more in-depth analysis in the following.

atemporal and immutable	atemporal and mutable
temporal and immutable	temporal and mutable

Still, it is not difficult to see that the second option is not actually possible. For note that by definition 2, something is mutable only if it exists in time and, by definition, something is atemporal if and only if there is no time at which it exists. Thus, since no atemporal entity can be mutable with respect a property, we get the following equivalence:

$$\text{atemporal} \Leftrightarrow \text{atemporal and immutable.}$$

The possibility of the third option depends on our conception of time. If, following Aristotle, we assume that time strictly depends on change and, thus, on mutability, then the only way for an immutable being to exist is being timeless, so that also the third option turns out to be impossible. On the contrary, if we assume that time is somehow independent of change, then that option is viable. Since we do not intend to take a stand towards to the dependence of time on change, we do not exclude the possibility of immutable but temporal entities.

In conclusion, our framework allows for three distinct conceptions of the existence of God:

(**1**) God might be atemporal, and so immutable;
(**2**) God might be temporal and immutable;
(**3**) God might be temporal and mutable.

In options (1) and (2) God's knowledge cannot change.

The last couple of concepts concerns the metaphysics of time. On a tensed metaphysics of time the present has a privileged status and it is a dynamic property. We will call the metaphysics of time that satisfy these criteria standard tensed metaphysics of time. Hence, Presentism, Growing Block Theory, Moving Spotlight Theory are standard metaphysics of time, differing only with respect to the ontological status they attribute to instants that are not present. We will deal with a non-standard metaphysics of time in Section 5.

In an untensed universe, on the contrary, the present has no privileged status and all moments of time are on par. The typical metaphysics of such universe is the Block Theory, according to which every time exists and in which only B-relations among moments of time are metaphysically significant.

3 Untensed Universe

Let us start with combining options (1)–(3) with untensed (i) and tensed (ii) metaphysics of time, first considering all the conceivable options and then excluding the inconsistent ones.

If the universe is non-tensed, things are, all considered, not particularly problematic. In fact, as a first basic result, we obtain that in a untensed universe God can be omniscient whether He is temporal or not. To be sure, if the world is untensed, the two following combinations are possible.

(1)+(i) There is a timeless and immutable God in a untensed world. This position is represented in literature by Rogers (2007). She believes that a perfect being must be immutable and timeless and that such a being cannot be omniscient in a tensed world. Therefore, since God is actually omniscient, the world is untensed.

(2)+(i) There is a temporal and immutable God in a untensed world. To the best of our knowledge, this position is not represented in literature. This notwithstanding, if temporal and immutable entities are assumed to be possible, then the position is viable and can be used to account for the immanence of God in a untensed world.

Let us now assess these two possibilities in a logical framework.

LANGUAGES

As a first step, let us introduce the languages we are going to interpret.

Definition 1 *Language of pure knowledge.*

The language of pure knowledge, based on a set P of propositional variables, is defined according to the following rules:

$p \mid \neg\varphi \mid (\varphi \wedge \varphi) \mid [now]\varphi \mid \Box\varphi \mid \boxminus\varphi \mid \mathbf{K}\varphi$, where $p \in P$.

These languages share a common stock of temporal operators, whose intended interpretation is as follows:

1. $\Box\varphi$ states that φ is true at any time.
2. $\boxminus\varphi$ states that φ is true at any present time.

Remark 1 *As we will see, these operators turn out to coincide in a static universe, since the notion of presentness is interpreted in an indexical way. Accordingly, what is present is nothing else as what is present with respect to a certain instant t, and what is present with respect to a certain instant t is simply what is actual at t. Hence, to be true at any present time coincides with being true at any time* simpliciter.

Definition 2 *basic concepts.*
(1) *time invariance:* $\varphi \rightarrow \Box\varphi$
(2) *present invariance:* $\varphi \rightarrow \boxminus\varphi$
(3) *omniscience:* $\Box\varphi \rightarrow \mathbf{K}\varphi$
(4) *knowledge stability across time:* $\mathbf{K}\varphi \rightarrow \Box\mathbf{K}\varphi$
(5) *knowledge stability across the flow of time:* $\mathbf{K}\varphi \rightarrow \boxminus\mathbf{K}\varphi$
(6) *unconditional knowledge stability:* $\mathbf{K}\varphi \rightarrow \Box\boxminus\mathbf{K}\varphi$

In our setting *complete* propositions are to be identified with *time invariant* propositions, i.e. propositions whose truth value is time independent. Nothing substantial depends on this identification. In fact, as we will see, propositions concerning what is *now* the case are time invariant, even if *what* is now the case changes across time. The definition of omniscience depends on the definition of time invariant propositions, since science concerns complete, and hence invariant, propositions. In fact, an incomplete proposition has no truth value in itself. Importantly, *defining omniscience with respect to propositions that are incomplete would immediately beg the question against the possibility of an immutable omniscient agent*. For, suppose that an incomplete proposition is known at time t_0. Then,

- at t_0, $\mathbf{K}\varphi$ and $\neg\Box\varphi$
- for some t, at t, $\neg\varphi$
- for some t, at t, $\neg\mathbf{K}\varphi$
- at t_0, $\mathbf{K}\varphi$ and $\neg\Box\mathbf{K}\varphi$

Thus, knowledge of incomplete propositions is not stable, and no immutable agent can possibly know such propositions. The last three concepts characterize knowledge stability. As we will see, they turn out to be different only if a dynamic conception of time is assumed.

Definition 3 Model.
A model is a tuple $M_0 = \langle W, T, t_0, K, V \rangle$ *where*

(i) W *is a set of histories*
(ii) T *is the set of times*
(iii) $K \subseteq W \times W$ *is a relation on* W
(iv) $V : P \rightarrow \wp(W \times T)$ *is a modal valuation.*

In addition, K is assumed to satisfy the following conditions:

K1: $K(w, w)$
K2: $K(w, v) \Rightarrow K[v] \subseteq K[w]$, where $K[w] = \{v \mid K(w, v)\}$

The definition of truth at a stage of a world can be then defined along the following lines.

Definition 4 Truth at a world in a model.

$M, (w, t) \models p \Leftrightarrow (w, t) \in V(p)$
$M, (w, t) \models \neg\varphi \Leftrightarrow M, (w, t) \not\models \varphi$
$M, (w, t) \models \varphi \wedge \psi \Leftrightarrow M, (w, t) \models \varphi \; and \; M, (w, t) \models \psi$
$M, (w, t) \models [now]\varphi \Leftrightarrow M, (w, t) \models \varphi$
$M, (w, t) \models \Box\varphi \Leftrightarrow \forall t'(t' \in T \Rightarrow M, (w, t') \models \varphi)$
$M, (w, t) \models \boxminus\varphi \Leftrightarrow \forall t'(t' \in T \Rightarrow M, (w, t') \models \varphi)$
$M, (w, t) \models \mathbf{K}\varphi \Leftrightarrow \forall v(K(w, v) \Rightarrow M, (v, t) \models \varphi)$

Two traits of this definition are worth noting. In the first place, in accordance with the block universe intuition that no temporal point is privileged, a proposition like $[now]\varphi$ is intended as stating that φ is true at the point at which it is uttered. In the second place, again in accordance with the block universe intuition, there is no distinction between what is true at all times and what is true at all present times since $M, (w, t) \models \Box\varphi \Leftrightarrow M, (w, t) \models \boxminus\varphi$.

UNTENSED UNIVERSE: PRINCIPLES ON KNOWLEDGE

The following principles are sound relative to the preceding semantics.

- **K** is a normal modality
- $\mathbf{K}\varphi \rightarrow \varphi$
- $\mathbf{K}\varphi \rightarrow \mathbf{KK}\varphi$

Furthermore, by the truth conditions of $[now]\varphi, \Box\varphi, \boxminus\varphi$, we obtain the following equivalences:

- $[now]\varphi \leftrightarrow \varphi$, by def. $\models$
- $\mathbf{K}([now]\varphi \leftrightarrow \varphi)$, by def. $\models$
- $\mathbf{K}[now]\varphi \leftrightarrow \mathbf{K}\varphi$, by def. $\models$

Hence, $[now]$ can be eliminated without consequences. Finally

- $\Box\varphi \leftrightarrow \boxminus\varphi$, by def. $\models$
- $\mathbf{K}\Box\varphi \leftrightarrow \mathbf{K}\boxminus\varphi$, by def. $\models$
- $\Box\mathbf{K}\varphi \leftrightarrow \boxminus\mathbf{K}\varphi$, by def. $\models$

Hence, the distinction between truth across times and truth across present times, i.e. through the flow of time, plays no role as to knowledge. To be sure, it plays no role at all, since it is a mere verbal distinction.

UNTENSED UNIVERSE: DIVINE KNOWLEDGE

Since omniscience is defined as knowledge of the truth of any true complete proposition, we obtain the following conclusion. In a static universe, *it is possible for God to possess a complete and stable knowledge of all truths*. In fact, assuming $\Box\phi \rightarrow \mathbf{K}\phi$, we have

1. $\Box\phi \rightarrow \Box\mathbf{K}\phi$
2. $\Box\phi \leftrightarrow \Box\mathbf{K}\phi$
3. $\Box\phi \leftrightarrow \boxminus\mathbf{K}\phi$

In conclusion, on this first metaphysical model, no problem arises as to the possibility of complete and stable divine knowledge, both relative to a timeless and immutable God and relative to a temporal and immutable God.

4 Tensed universe

Let us now consider a standard tensed world. The following combination seems to be coherent because God, being temporal and mutable, can "follow" the flow of time:

(3)+(ii) There is a temporal and mutable God in a tensed world. This position is represented in literature by Craig (2000) and (2001), De Weese (2004), Mullins (2016).

The following model analyzes this possibility.

Definition 5 Model.
A model is a tuple $M_0 = \langle W, T, t_0, K, V\rangle$ *where*

(i) W *is a set of histories*
(ii) T *is the set of times, with* $t_0 \in T$
(iii) $K \subseteq W \times W$ *is a relation on* W
(iv) $V : P \to \wp(W \times T)$ *is a modal valuation.*

The index of M_0 refers to the privileged instant t_0 which is present. In addition, K is assumed to satisfy the previous conditions:

K1: $K(w, w)$
K2: $K(w, v) \Rightarrow K[v] \subseteq K[w]$, where $K[w] = \{v \mid K(w, v)\}$

The definition of truth at a stage of a world can be then defined along the following lines.

Definition 6 Truth at a world in a model given a privileged present time.

$M_0, (w, t) \models p \Leftrightarrow (w, t) \in V(p)$
$M_0, (w, t) \models \neg\varphi \Leftrightarrow M_0, (w, t) \not\models \varphi$
$M_0, (w, t) \models \varphi \wedge \psi \Leftrightarrow M_0, (w, t) \models \varphi \; and \; M_0, (w, t) \models \psi$
$M_0, (w, t) \models [now]\varphi \Leftrightarrow M_0, (w, t_0) \models \varphi$
$M_0, (w, t) \models \mathbf{K}\varphi \Leftrightarrow \forall v(K(w, v) \Rightarrow M_0, (v, t) \models \varphi)$
$M_0, (w, t) \models \Box\varphi \Leftrightarrow \forall t'(t' \in T \Rightarrow M_0, (w, t') \models \varphi)$
$M_0, (w, t) \models \boxminus\varphi \Leftrightarrow \forall t'(t' \in T \Rightarrow M_{t'}, (w, t) \models \varphi)$

Again, two traits of this definition are worth noting. In the first place, in accordance with the tensed universe intuition that there is a privileged temporal point, a proposition like $[now]\varphi$ is intended as stating that φ is true precisely at that point. In the second place, again in accordance with the tensed universe intuition, there is a specific distinction between what is true at all times and what is true at all present times, since the truth at all present times depends on what happens in models that differ from the model in which the valuation occurs as to the position of the present time. As a straightforward consequence of the definition we obtain the following

Corollary 1 $M_0, (w, t) \models [now]\varphi \Leftrightarrow M_0, (w, t) \models \Box[now]\varphi$.

Hence, a proposition like $[now]\varphi$ is time-invariant in a certain model, even if it is not time-stable, since

Corollary 2 $M_0, (w, t) \models [now]\varphi \not\Leftrightarrow M_0, (w, t) \models \boxminus[now]\varphi$.

In fact, it is not difficult to see that, if φ is true at t_0 and false at t_1, then $[now]\varphi$ is true at t_0 while $\boxminus[now]\varphi$ is false there.

TENSED UNIVERSE: PRINCIPLES ON KNOWLEDGE

The following principles are sound relative to the preceding semantics.

- **K** is a normal modality
- $\mathbf{K}\varphi \rightarrow \varphi$
- $\mathbf{K}\varphi \rightarrow \mathbf{KK}\varphi$

Furthermore, by the truth conditions of $[now]\varphi$, we obtain that:

- $[now]$ is a normal modality
- $[now]([now]\varphi \leftrightarrow \varphi)$

Finally, by the truth conditions of $[now]\varphi, \Box\varphi, \boxminus\varphi$, we obtain that:

- $[now]\varphi \leftrightarrow \Box[now]\varphi$
- $[now]\varphi \not\leftrightarrow \boxminus[now]\varphi$

TENSED UNIVERSE: DIVINE KNOWLEDGE

Since omniscience is defined as knowledge of the truth of any true complete proposition, we obtain the following conclusion. In a standard tensed universe, it is *impossible for God to possess a complete and stable knowledge of all truths*.

Proposition 1 *omniscience* vs *stability.*

An omniscient being cannot possibly have a knowledge that is stable across the flow, and so cannot possibly have an unconditional stable knowledge. For, given the definitions of complete proposition and stability with respect to the flow of time, $\Box\varphi \rightarrow \boxminus\mathbf{K}\varphi$*, and so* $\Box\varphi \rightarrow \boxminus\varphi$*, which fails in any scenario in which a change is occurred. To be sure, since* $[now]\varphi \rightarrow \Box[now]\varphi$*, we would obtain* $[now]\varphi \rightarrow \boxminus[now]\varphi$*, which fails in general.*

As a conclusion, position **(3) + (ii)** is perfectly represented by this model.[3]

Let us now consider the last possible option:

(1)+(ii) There is a timeless and immutable God in a tensed world.

> In this option, there is no time at which God exists and the present is privileged over other times. According to this view, God is again a perfect entity that is immutable and that transcends the world, thus being timeless. Probably, Stump and Kretzmann (1981), following a certain interpretation of Anselm and Aquinas, accept a position like this.

[3] From a combinatorial point of view, we should analyze other combinations: for instance, the combination **(2) + (ii)** "There is a temporal and immutable God in a tensed world". This option seems not to be coherent. If God's knowledge is immutable, then He cannot know at two different instants of time that it rains now and that it does not rain now. Then, He cannot be omniscient because He does not the truth values of some propositions. Therefore, we can discard this combination. In addition, the combination **(3) + (i)** "There is a temporal and mutable God in a untensed world" is puzzling. If the change in God concerns His knowledge *only*, then the position seems to be incoherent. Since God is omniscient and the world is timeless, at some time t God must know the facts that obtains at every time. Now, suppose that at a time t', subsequent to t, God's knowledge is changed. Because God's knowledge at t is complete, how can it be changed at t'? It seems that it can change only by reduction, that is only if God does not possess at t' some knowledge He had at t. Thus, at t' God would be no more omniscient. Perhaps, this combination is possible if change involves some other properties of God.

Given the centrality of this alternative for the Compatibilism / Incompatibilism debate and given its subtleties, we will devote the next section to it. We will see that this alternative is incompatible with a standard tensed metaphysics of time, but compatible with at least one non-standard version of such a metaphysics. But before passing to discuss the combination **(1)+(ii)**, we can briefly summarize our path. Our intuitive judgements seem to push us toward two extremes positions. On one hand, we can adopt Katherine Rogers' frozen universe, where God is immutable, atemporal, and omniscient. The cost of this solution is the reality of flow of time. On the other hand, we can dive in Craig's tensed universe, where God is still omniscient at the cost of His immutability. We lost the transcendence of God relative to the world. We called these models *homogeneous* since God's temporal status reflects the temporal status of the world: if God is omniscient and the world is untensed, then God is immutable and atemporal; on the contrary, if God is omniscient and the world is tensed, then God is mutable and temporal.

It is then not difficult to understand why option **(1)+(ii)** is so desirable: it combines the intuitive force of the tensed theory with the sovereignty of God over the world, still keeping the omniscience. As we will see, to defend this option is a fairly complicated philosophical task, but we will argue that even if the most prominent dynamic metaphysics of time cannot account for this *desideratum*, nevertheless there is a metaphysical framework in which God is atemporal and omniscient in a tensed world.

5 A possible Heterogeneous Model

The previous models show that our intuitions about the relationships between omniscience, stability, and temporal existence of God are substantially correct. We could sum up these results as:

- If God has access to the propositions of kind $[now]\varphi$, then His knowledge is complete, but is unstable (He changes, while being omniscient);
- If God does not have access to $[now]\varphi$, then His knowledge is stable, but is incomplete (He is immutable, but not omniscient).

However, we think that not everything is lost for the Compatibilist who accepts a tensed metaphysics of time.

The idea we will pursue is to distinguish between temporal reference frames and an atemporal, divine reference frame ϵ, and to model divine knowledge in terms of the relations between them. In particular, we are going to assume that the world is fragmented and every fragment is a temporal frame represented by a temporal model. The crucial point is that the divine perspective, represented by a specific eternal model, is suitably connected with all the fragments.

Definition 7 *Language of perspectival knowledge.*

The first thing to do it is to enrich our language by introducing a language devoted to represent the perspectival knowledge. This language, based on a set P of propositional variables and a set I of temporal indices, is defined as follows:

$p \mid \neg\varphi \mid (\varphi \wedge \varphi) \mid [i]\varphi \mid \Box\varphi \mid \boxminus\varphi \mid \mathbf{K}\varphi$, where $p \in P$.

The language of perspectival knowledge differs from the language of pure knowledge in the way in which the present time is conceived of. To be sure, the intended interpretation of a proposition like $[now]\varphi$ is that φ is true at the present time, while the intended interpretation of a proposition like $[i]\varphi$ is that φ is true at time i. Hence, while a user of the first language (typically a temporal agent) is able to refer to the present time only by means of an indexical now, the user of the second language (typically an atemporal agent) refers to the present time by means of its proper name i.

Definition 8 Eternal Model.
An eternal model is a tuple $M_\epsilon = \langle W, T, \tau, \epsilon, K, V\rangle$ where

(i) W is a set of histories;
(ii) T is the set of times;
(iii) $\tau : I \to T$ is an index valuation;
(iv) ϵ is the eternal perspective;
(v) $K \subseteq W \times W$ is a relation on W;
(vi) $V : P \to \wp(W \times T)$ is a modal valuation.

The index of M_ϵ refers to the eternal perspective ϵ, and K is assumed to satisfy the usual conditions. Intuitively, τ assigns to each index in I an instant of time $\tau_i \in T$. The eternal perspective plays in this model

the role played by instants of time in tensed models, providing a way to connect the eternal perspective with the temporal perspectives of tensed models, and so a way to link the truth of a tensed proposition as assessed from the point of view of a temporal agent and the truth of the same proposition as assessed from the point of view of an eternal agent.

Definition 9 Truth at a world in a model given a privileged present.

The language interpreted by eternal models is the language of perspectival knowledge.

$M_\epsilon, (w,t) \models p \Leftrightarrow (w,t) \in V(p)$
$M_\epsilon, (w,t) \models \neg\varphi \Leftrightarrow M_\epsilon, (w,t) \not\models \varphi$
$M_\epsilon, (w,t) \models \varphi \wedge \psi \Leftrightarrow M_\epsilon, (w,t) \models \varphi \; and \; M_\epsilon, (w,t) \models \psi$
$M_\epsilon, (w,t) \models [i]\varphi \Leftrightarrow M_\epsilon, (w,\tau_i) \models \varphi$
$M_\epsilon, (w,t) \models \Box\varphi \Leftrightarrow \forall t'(t' \in T \Rightarrow M_\epsilon, (w,t') \models \varphi)$
$M_\epsilon, (w,t) \models \boxminus\varphi \Leftrightarrow \forall t'(t' \in T \Rightarrow M_\epsilon, (w,t') \models \varphi)$
$M_\epsilon, (w,t) \models \mathbf{K}\varphi \Leftrightarrow \forall v(K_\epsilon(w,v) \Rightarrow M_\epsilon(v,t) \models \varphi)$

As we can see, there is no difference between invariance and stability from the eternal point of view, and all that is true at a certain present time t_i is true with respect to the eternal reference frame at that time as seen by the eternal agent. In addition, and in accordance with our intuitive interpretation, $[i]\varphi$ is a stable proposition and it is true in the model just in case φ is true at τ_i.

FRAGMENTED UNIVERSE: PRINCIPLES ON KNOWLEDGE

The following principles are sound relative to the preceding semantics.

- **K** is a normal modality
- $\mathbf{K}\varphi \rightarrow \varphi$
- $\mathbf{K}\varphi \rightarrow \mathbf{KK}\varphi$

Furthermore, by the truth conditions of $[i]\varphi, \Box\varphi, \boxminus\varphi$, we obtain that:

- $[i]\varphi \leftrightarrow \Box[i]\varphi$
- $[i]\varphi \leftrightarrow \boxminus[i]\varphi$

As in the case of a static universe, *it is possible for God to possess a complete and stable knowledge of all truths*. Still, what is more interesting, in the present case we are able to relate in an appropriate way what is true from an eternal perspective and what is true from a temporal perspective. In fact, given that both temporal and eternal models are based on the same kind of frame $\langle W, T, K \rangle$, the following crucial link shows up:

Proposition 2 $M_\epsilon, (w, t) \models [i]\varphi \Leftrightarrow M_{\tau_i}, (w, t) \models [now]\varphi$

Hence, for every instant of time t, a proposition φ is presently true at t precisely when the proposition stating that φ is true at that instant of time is true in the eternal model. Thus, we obtain the following fundamental result: *if the world is fragmented according to the flow of time, then what is now actual in each fragment coincides with what is actual at an instant of time of the eternal model, so that what is now actual in each fragment is known by God as actual at that very instant in the eternal model*.

6 Conclusion

In this work, our aims were manyfold. Firstly, we argued that a satisfying analysis of the compatibility (viz. incompatibility) between omniscience and immutability demands a detailed study of the underlying metaphysics of time. More effectively, we provided a conceptual analysis of three pairs of concepts involved in the discussion: Temporality/Atemporality of God, His Immutability/Mutability and, in the end, the reality or unreality of tense. The most common and most (from a certain point of view) natural models are those we called *homogeneous* framework since, to keep omniscience, God's temporal nature is reflected into World's temporal nature: mutable, dynamic world can be known only by mutable and dynamic God; in contrast, atemporal, immutable God can know just an immutable, static, eternalist world. And it is not surprising that the recent debate focused on these two crucial points. Our third point was to rigorously characterize the previous conceptual analysis through a multi-modal semantic framework which includes a untensed version and a tensed version. Within this framework we actually *proved* both that to keep an omniscient God in a standard tensed universe we must give up God's immutability and that to keep

an omniscient God and His immutability we have to abandon the tensed features of the world. Our last point is more constructive since we think that there is actually the possibility of an omniscient, immutable God *and* of a tensed Universe (though this a non-standard tensed Universe).

The conceptual move is to adopt a specific metaphysics of time based on the idea that the world is fragmented and that every fragment is only known from a specific perspective. Then we enriched our framework by adding a formal setting for perspectival knowledge. Under these assumptions we *proved* that God eternally knows as actual what is actual in every fragments. We think that this could be a satisfactory answer to the *conundrum* about what God can (or cannot) know.

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The truth about Osmo

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Abstract

Richard Taylor advances an interesting fatalistic narrative based on the story of Osmo (Taylor, 2015, [17, pp. 44–51]). After presenting both the fictional character of Osmo and Taylor's arguments, we offer a reply that preserves two features: the contingency of future facts and Osmo's free-will, despite his "quietist" attitude. Finally, we defend the acceptability of Osmo's attitude, even if we don't end up with a fatalistic metaphysical description of the world. This entails that there are attitudes not grounded in reasons, but rather in things such as habits, the "phenomenology of sensations", and so on. If this is so, then the final conclusion on metaphysical claims may have a very weak bearing on human behaviour. In order to avoid understanding Osmo's scenario as if it necessarily entails fatalism, the approach connecting Ockhamism and eternalism will be important.

Keywords: Fatalism; Free-will; Theological Fatalism; Ockhamism

1 Osmo and the Book of Destiny

Before describing a version of Osmo's story,[1] we'll consider a few premises required to understand some aspects of the relation between this story and fatalism, especially in its theological version.[2] The first premise asserts that God knows all truths and the second premise asserts

[1]This research has been supported by CNPq Brazil.

[2]On this version, it is relevant to know the consequences for free-will, if any, of divine prescience, given that, allegedly, divine prescience is incompatible with free-will.

that God cannot believe in any falsehood. Thus, God knows that the Moon is not made of cheese, though that simply means that he knows it to be true that the proposition "The Moon is made of cheese" is false. Despite the fact that it is seemingly impossible to know a falsehood, it is possible that someone has the false belief that the Moon is made of cheese. God's knowledge of all truths, however, implies that he cannot sustain such a belief. God's beliefs about the future will figure in one version of the fatalist argument, which we'll discuss later on.

Suppose now that God, who is omniscient, chooses to reveal a set of facts about the world, by writing a book about the life of a certain person, named "Osmo". So God then leaves several copies in many bookshops, knowing that, after finding this book, Osmo will not resist the temptation of buying it, due to its title: *The Life of Osmo*. Giving that God knows all truths about the life of Osmo, he chooses not to leave out of the narrative at least a few details about the past, present and future of this character.

Osmo finds this book and then begins to recognize himself in the first pages. He has no doubts, among other things, about the recognition of his relatives' names, the city and house where he lived in his first years, and other convincing details. The book is written in the present tense, narrating facts as if they are taking place now: "Osmo is born at Mercy Hospital, Auburn, Indiana, in June 6, 1942." In fact, Osmo's life is reported in some detail; even the sadness he felt after the death of a loved one is described.[3] Osmo continues to read with relentless curiosity and dazzlement.

He then wonders who might be the author of such a book. "Could it be someone from the future or, who knows, myself even, writing about the past and sending the book through time-travelling?" – he considers. "No, it couldn't", for the narrated details are too many, not all of them being consciously registered before the reading itself.[4] The author

[3]Could the book reveal all facts about Osmo's life? I don't think so, given that it can be read by Osmo. As well as being immense, it would have to make references to itself, which would make it paradoxical. There would be, for instance, a version of Zeno's paradox, in which to read all references to readings already made would imply never finishing it.

[4]There are two curious facts about the relation between Osmo's life and the book. Osmo didn't know where he had left a ring he intended to give someone special. The book not only provided the narrative of that fact, but it also reminded Osmo where the ring was. Also, Osmo never found out who spread lies about himself in school, until he had the name of the fibber revealed by the book.

knows more about the life of Osmo than he himself does. In the bookshop, as expected, no one knew anything about the book or its author, who is never referred to or mentioned in the book itself. But the author could be no one other than God, for He is the only being that knows not only the past, but also the future.

Osmo then becomes inclined to think that the book has told him truths about his future, in the same way that it told him truths about his past. Naturally, this thought made him apprehensive about the book's contents: he is afraid of reading about things to come in his own life. But, quite inevitably, he ended up reading everything he could about his future. He read about things that came to happen just as they were described. The book narrated every event in such a precise order, and with such accuracy that everything he read eventually took place, even those things that he wished to avoid at all cost. So, as the book showed anyhow, our character gradually came to look upon fate with acquiescent eyes. Not even the most stoic of philosophers would be able to compete with him, such was the degree of conformity to which he was subjected. And there is no difficulty in understanding why: the book was never wrong, which reinforced his opinion that God had been written it. It was unfortunate to know one's own future, and Osmo wished never to have known so much about himself.[5]

2 Taylor's Logico-Semantic Argument

Why did Osmo become a fatalist? Couldn't he, despite having read this intriguing book, end up believing in some form of compatibilism[6] or libertism?[7] A fatalist like Taylor could reply along the following lines: there is a true proposition for every fact in Osmo's life, and he knows (or is in a position to know) some of those propositions in advance. The fatalism he would embrace was motivated by a psychological reason, however it would be justified by a logico-semantic one:

[5]Details of the story were modified, curtailed or omitted. One could say we have only one version of Osmo's story. However, I think that the presented version preserves the relevant details concerning the debate on fatalism.

[6]"Compatibilist" means anyone who strives to make determinism and free-will compatible.

[7]"Libertist" means anyone who accepts the incompatibility between determinism and free-will but refuses the former as a way of asserting the latter.

> *"(1) there existed a set of true statements about his life, both past and future, and (2) he came to know what those statements were and to believe them. Now the second of these two considerations explains why, as a matter of psychological fact, Osmo became fatalistic, but it has nothing to do with the validity of that point of view. Its validity is assured by (1) alone."* (Taylor, 2015, [17, p. 49])

Taylor, then, seems to have no more than one version of the old logical fatalism. If P is true, then it is necessarily true, and if it is necessarily true, then it is unavoidable. For Taylor, fatalism is a thesis about "inevitability": "*Osmo's fatalism is but the understanding that things which take place according to the book are inevitable* (Taylor, 2015, [17, p. 48])." But Taylor's story has a great rhetorical appeal, which mainly comes from the irresistible psychological force with which Osmo is driven to embrace a "quietist" attitude.[8] Nevertheless, here we'll defend the position that Osmo's fatalist conclusion is not the only possible one, though his attitude is acceptable.

3 On the Intelligibility of Osmo's Story

One possible criticism of Osmo's story could be to point out extravagance. There is something odd about believing that somebody who knows the undesirable outcome of an action, wanting firmly to avoid it, ends up carrying it through. What could explain it? The mechanism by which Osmo's actions have their outcomes remains obscure. It seems that Taylor incurs what Penelope Mackie dubbed "popular fatalism":

> *"Fatalism in this sense must be distinguished from the view (sometimes labeled "popular fatalism") that is associated with the slogan "what will be will be, regardless of what I do", and implies that my*

[8] Originally, "quietism" described a resigned and conformist state of mind, void of desires or passions. As a mystical-Christian proposal, it was realized by the Jesuit monk Luis de Molina (1535–1600). However, the concept can be used to signify much more than a medieval Christian attitude. In the general sense in which it occurs here, it has no further relation with the Christian context whence it originated. The word is thus borrowed from it. In this special sense, the word can be used to refer a resigned state of mind in any context, i.e., Greeks' *ataraxia*, Hindu or Buddhist analogs, and so on. In fiction, the Jedis from the *Star Wars* series present some quietist elements, especially the wisest, like Master Yoda.

> *actions are causally irrelevant to what comes about. The logical fatalist claim that I never have the power to do other than I actually do (e.g., that if I do not go to the air raid shelter, it is not in my power to go there) must be distinguished from the (absurd) claim that if I were to do something different (e.g., go to the air raid shelter), this would make no difference to the outcome (e.g., to whether or not I am killed by a bomb).*" (Mackie, 2015, [7, p. 129, footnote 2]).

If Taylor is committed to this version of fatalism, we may not feel very compelled by his narrative. However, to attribute Taylor such an implausible doctrine is too uncharitable. If Osmo's story can be made to fit a more assertive form of fatalism, then we should understand it that way. But how can we do so?

4 The Myth of Oedipus King

In *Poetics* [1], Aristotle considers "Oedipus Rex" to be the most beautiful of tragedies. Written by Sophocles (496–406 b.C.) c. 427 b.C., this work embodies the clash between man and fate (Sophocles, 1991, [16]). In tragedies, a certain kind of human being is represented as unsatisfied in specific ways with his own destiny: his dignity is dependent on his struggle against what he is powerless to change. This tragedy tells us that the young Oedipus would become king and wed his mother, after killing his own father. None of that is known to be true by Oedipus when he carries out such actions. However, Oedipus does each of those things after desperate attempts to avoid his fate announced by the oracle. He did not know that he was killing his father, the king of Thebes, when he was killing him. In fact, he had only run away from the place where he grew up to the outskirts of that city in order to avoid killing his father, whom he thought was someone else. Marrying his mother (unknowingly), the queen, was supposedly a reward bestowed upon him by the city of Thebes, though it was also something he was trying to avoid by his escape. In principle, knowing one's fate and trying to avoid it does not guarantee salvation. The event of Oedipus' escape was causally efficient in the fulfillment of his tragic destiny, i.e., if he had not acted as he did, he would not have had such a fate befall him. The story of Oedipus cannot be compared to popular fatalism.; my suggestion is that we should approach Osmo similarly. Osmo knows some

things about his future, but would never imagine how each of the components of his present life would come together to engender a plot, as he is unable to anticipate every consequence of his actions. That helps us to make sense of Osmo's story.

An important observation: Osmo's story is compatible with the metaphysical doctrines that are usually associated with fatalism. Since Osmo's actions are causally efficient, determinism, the thesis according to which the past determines the future, could explain the book (cf. Taylor, 2015, [17, p. 42]). Eternalism, the thesis according to which there is no ontological distinction between past, present and future, might also do. In this paper, we'll defend that one possible interpretation of the latter shows that it is not fatalistic, conveying instead an unfavorable reading to fatalism.

5 Other Difficulties

Taylor could argue that his logico-semantically indexed fatalism carries no commitment to any form of determinism. He makes it seem that determinism is indifferent, despite recognizing that the doctrine called "determinism" is a fatalistic one. However, the opposite does not follow: the so-called logical fatalism does not have to be deterministic. Taylor's fatalism is a thesis about the inevitability of the future. But the notion of *inevitability* does not have to be a modal one, i.e., it need not imply *inevitable in all possible worlds*.

Philosophers who object to fatalism tend to make that mistake, considering "inevitability" to entail something like "there is no world where it doesn't...". But how inevitable must a world be in order to be a fatalistic one? For Taylor, it suffices that Osmo is unable to follow or avoid a certain course of events and, as a consequence, the conditions for fatalism are satisfied (Taylor: 2015, [17, pp. 52–53]). Taylor seems to weaken his fatalistic thesis excessively. He would have to admit that the following narrative is a case in which fatalism still applies:

Osmo was destined to suffer a severe accident. And no matter how hard he tried to avoid it, whatever his efforts were to escape it, there he was, fulfilling what the book of fate had reserved for him. But, at some point, something strange seems to occur: his luck changes due to miraculous forces. Suppose that Osmo causes a great impression in some demon, who ends up falling in love with him. After long and careful considerations, the demon decides to in-

tervene, saving Osmo from his tragic fate. A genuine miracle takes place and Osmo escapes from what would have been a dire end.[9]

In this narrative, the world cannot be said to be fatalistic. If it was, whatever the book reports would have to be unavoidable. Whatever necessity involved would have to be sufficiently strong so that there would not be any viable alternatives. From the kinds of available necessities, i.e., logical, metaphysical or nomological ones, none is such that it cannot be fatalistic. However, one of these necessities may or may not be fatalistic, depending on its force. If deterministic worlds (where nomological necessities take place) are worlds subject to miracles, then those worlds don't contain any type of fatalism. But are there deterministic worlds subject to miracles? According to Sehon (2011), there are such worlds. And that is because it is not logically impossible for there to be an entity (IG)[10] capable of bringing about a state of affairs unforeseen by the laws that govern the relationships holding between parts of a world. Therefore, in some possible world there must be an entity capable of performing miracles, "miracle" here being understood as an alteration of whatever was determined by the laws of nature. Even if IG is possible, it still has to exist in order to perform miracles. Despite IG's possibility, this entity has to become actualized in order to perform miracles". If it is a merely *possibile* entity, then fatalism is true[11], because nothing could prevent the tragic end of Osmo.[12] Determinism will then be sufficient for fatalism, if we understand fatalism to be the doctrine that Taylor describes.

Couldn't Taylor allow for a miraculous intervention? Some form of argument is needed to support that. In fact, Taylor combines this with a miracle-compatible narrative, for a) he warns that the notion of inevitability is a weak (non modal) one; and b) he tells us a story in which God seems to intervene in the world, or that at least can be conceived as such an intervening entity.

[9]Thanks to my friend Hugo Luzio for the idea of the story about miracles and others interesting insights.

[10]Intervening God (Sehon, 2011, [15]).

[11]In that case, the demon exists (or acts) in some world, but not in this one.

[12]Supposing that only a supernatural being is capable of performing miracles. But that is unimportant. What matters is that any condition capable of realizing a miracle be blocked or does not actually exist.

6 Could Osmo be both a Libertist and a Quietist?

As already said, "quietism" denotes a resigned state of mind. To be a genuine fatalist, Osmo would have to build a philosophical argument, impervious to objections. Let us see some arguments that Osmo could consider.[13]

1. Classical Fatalism
   (a) There is a true proposition for every future fact about Osmo's life;[14]
   (b) Those propositions being true, everything happens necessarily;
   (c) Therefore, Osmo's necessary future makes it unavoidable.

Classical fatalism has a theological version. To state it, we need only to adjust (a). Let (a) be replaced by (a′) God knows a true proposition for every future fact about Osmo's life. How could Osmo avoid classical fatalism, as expressed in the above versions? Could Osmo reject the first premise? As far as we know, Osmo is inductively convinced that this premise is true. Setting aside qualms about the questionability of inductive reasons, we don't believe that our character would reject inductive beliefs derived from his experience with the book. The solution does not seem to reside here. As is also common within contemporary philosophy (Haack, 1998, [5]; Iacona, 2007, [6]), Osmo could protest a modal fallacy implied in the interpretation of the second premise. The necessity operator must have a wide scope over the conditional $\Box(T'P' \rightarrow P)$, rather than a short scope over its consequent, as in $(T'P' \rightarrow \Box P)$. That is the classic refutation offered to logical fatalism, apparently endorsed by Taylor. He is aware of that and remains convinced. The scope confusion would be, according to him, a simple distraction perpetrated by the libertist and other opponents of fatalism (Taylor, 2015, [17, pp. 52–53]). Meanwhile, if this were the only version available to engender a fatalistic argument, few philosophers would have become convinced. But

[13] One can say that in my version of the story, Osmo is a rigorous philosopher who does not let himself be convinced by sophistry, or even by mere appearances.

[14] In the book, many propositions about many things that are a part of Osmo's life are absent. But if Osmo concludes that the book was written by God, and if he knows that God is all-knowing, then he knows that God knows all true propositions about his life, even those he never revealed.

fatalists can do better than that by offering perfectly valid arguments intended to ground the feelings of Osmo about his fatalistic life." The following version, also widely discussed, does not end up in this modal confusion:

2. Contemporary Fatalism
   (a) Osmo has no choice concerning the proposition "Osmo is sitting down at t" being true one million years before t;
   (b) Necessarily, if Osmo has no choice concerning the truth of "Osmo is sitting down at t", then Osmo is sitting down at t;
   (c) Therefore, Osmo has no choice whether or not he is sitting down at t.[15]

The contemporary version also has a theological counterpart. As before, we can simply introduce the required changes in the stated premises. Let the first two premises be replaced by (a*) Osmo has no choice concerning God's belief in the truth of the proposition "Osmo is sitting down at t", in a time preceding t by one million years; and (b*) necessarily, if Osmo has no choice concerning God's belief in the proposition "Osmo is sitting down at t", and this proposition is true, then Osmo is sitting down at t. The rest follows in a similar fashion.

When put in these terms, the argument does not rest on any modal confusion. That is seemingly the most promising argument for logical fatalism. The problem with it is just that there are good replies in the extant literature. Merricks, for instance, accuses the argument of begging the question (Merricks, 2015, [8, pp. 84–107]). How one gets to its conclusion mirrors other possible solutions, such as Ockhamism. Meanwhile, Merricks deviates from Ockhamism in some fundamental aspects. Rather than invoking the distinction between "soft" and "hard" facts, Merricks avails himself of a truism: propositions are true in virtue of the facts they state, and not the other way around, i.e., the proposition "Snow is white" is true because snow is white, but snow is not white in virtue of that proposition's truth.

But how can this truism convince us that the argument, even in its more promising version, involves a fallacy? If we acknowledge this truism, then the truths about Osmo's future depend on what Osmo will do, or on what may happen to him. The *petitio principii* involves the fatalistic understanding of the first premises: the truth of "Osmo is sitting

[15] *Mutatis mutandis* for the false proposition "Osmo is sitting down at t".

down at t", in a time previous to t, entails that Osmo has no choice about sitting down at t.

Contemporary fatalism just assumes the thesis that is to be proved. Hence, it is true if and only if Osmo has no choice concerning the truth value of those propositions. But isn't "Osmo has no choice concerning..." precisely a statement of the fatalist thesis, and so, true only if fatalism is true? If this is so, Merricks dismantles the fatalistic argument in a simple, elegant way.[16]

> *"Nevertheless, I begin with Origen's insight: God's beliefs depend on the world. This has a corollary: for all S and all God's beliefs b, that S has no choice about whether God has belief b presupposes (in the sense of "presupposes" relevant to begging the question) that S has no choice about what God's having belief b depends on (in the sense of "depends on" in which God's beliefs depend on the world"* (Merricks, 2015, [8, p. 105])[17]

Another fruitful solution is Ockhamism. This solution employs a somewhat obscure distinction between propositions that, being true now, are in a dependence relation with future facts – technically labeled soft facts; and propositions that are true now *tout court* – whose technical name is hard facts. The former propositions' truth depends on what may or may not happen, such as: "I played my last soccer match today".

Hard facts, however, are not relational in the same sense, for they do not establish any connection between a time t and a future relative to t. For instance, the proposition "William of Ockham died in 1347" is a hard fact, for its truth does not depend on the occurrence of later facts. Ockham's use of the distinction between soft and hard facts provides an opportunity for challenging the *principle of the necessity of the past* (PNP) or the *fixed past constraint*. If Ockham has captured a distinction on which we can rely, then either there are exceptions to the rigidity with which the past must be availed, or the past is not necessary in a relevant sense. When considering the explanatory power of Ockham's distinction, we can gather that soft facts incur in a violation of (PNP) for certain cases. We can also accept something like the counterfactual ability to change the truth value of certain propositions (cf. Saunders (1966, [14]) and Plantinga (1974, [11])).

[16]The argument, in this case, assumes divine omniscience.

[17]For a counterpoint, see Fischer & Todd (2015, [4, p. 110–127]).

Both answers deny that (PNP) – whose defense is emphatic, for example, in Fischer (2016)[18] – is true, but they do it with differing force degrees. Devotees of "reverse causation" or theorists of the possibility of time travel can refuse even the stronger versions of the principle. Dummett, for instance, argued [2, 3] that changing the past does not involve any greater conceptual problems than changing the future, thus breaking with the standard opinion according to which the past is closed and the future is open. In his turn, Vranas acknowledges [20] at least one sense according to which changing the past is unproblematic, namely, if "to change" means to replace one past with another. If Dummett and Vranas are right, the most promising version of fatalism may not succeed. In fact, if the necessity of the past can be rejected, then logical fatalism, even in its most promising version, does not succeed either.

The Ockhamist solution either weakens or denies the necessity of the past. But it is not essentially different from Merricks' proposal, since both subscribe to the idea that truths about the past are grounded in the future (cf. Fischer & Todd, 2015, [4, p. 120]). Thus, the first premise can be true due to the fact that Osmo is sitting down in the future relative to t." But how is that solution grounded, since Osmo is not sitting down now?

As a libertist solution, Ockhamism includes yet another component, apt to explain why propositions about future facts are grounded. Ockhamists think there is a difference between the many contingent outcomes for each future fact. The difference is that one of them is *actual*. Such actuality is expressed by asserting that there is a "thin red line" on those facts that constitute actual future. But how does that help us moving forward in the consideration of Osmo's possible non-fatalism? The adoption of Ockhamism could merely tell us that God has revealed that future to Osmo. But since it is one of many futures, it is not necessary in the sense required by the fatalist.

To conclude our remarks about Ockhamism, we must say something about the meaning of expressions such as "X is the actual future". We'll opt for a particular solution that consists in the association

[18] Fischer defends an intuitive version of the principle, according to which we don't have now a choice concerning the past. Thus defined, the principle is not interpreted as if it meant the immutability of the past *tout court*, but rather the impossibility of choosing the past relative to ourselves. But could God change the past? Even if he could, he could not change one fact: that something, which can be modified, has happened in the past.

of Ockhamism with eternalism. Rea and Finch are responsible for understanding Ockhamism as an eternalist solution for libertism (Rea & Finch, 2008, [13, p. 231]). Their reasons are peculiar when related to the demand for grounding endorsed by several writers on the subject. In another important paper, Rea argues that the demand for grounding forces the presentist to choose between bivalence and free-will. If bivalence is the elected option, then the available ground forces the presentist to reject free-will (Rea, 2006, [12, p. 10]). Eternalism, on the contrary, is an option that provides us with adequate grounding, whose association with some determinism or fatalism (whatever its versions) is always disputable. Ockhamism is an alleged counter-example for whoever wishes to associate eternalism and fatalism. Having said that, we are now in a position to clarify the meaning of *X's actuality*. If eternalism and Ockhamism are associated, then the actual future is an existent future in the eternalistic way. God knows the future because it is actual, and not the other way around. In the eternalist interpretation of Ockhamism, one can adopt Plantinga's (1974, [11]) solution, which explains the power we have over the past in counterfactual terms: we could have turned some true propositions about our past into false ones. But, as we never did it, our choices resulted in facts such that the grounding for true propositions was provided.[19] This is the simplest and most efficient solution.

The book had been written in the form of a factual report. Ockhamism, however, only allows for profecies stated as conditionals: "*unless men from Nineveh repent*..." (Ockham, 1969, [10, p. 44]). But that imposes no difficulty upon us. The eternalist version of Ockhamism provides us with a ground to deal with contingent truths, in an actual future. The sense in which they are actual is non-temporal, being describable as events available or accessible to God, located in a McTaggartian *B-series* (McTaggart, 1908, [9]).[20] If the actual events located in that series are not necessary in any relevant sense, then we can refuse fatalism without major problems.

In the end, Osmo doesn't seem compelled to be a fatalist, and so, his

[19]The demand for a grounding can be understood as the prevalence of the idea that truth and falsehood depend on the world. Thus, if a proposition is true, it is because it describes how the world is. When from the truth of a proposition, we say that the facts in virtue of which that proposition is true ground it.

[20]The B-series is described as situating events according to criteria such as anteriority, simultaneity and posteriority (cf. McTaggart, 1908, [9]).

quietist attitude is merely emotional or psychological. But why does Osmo, behaving as a quietist, even after carefully considering all available arguments against fatalism, bear any trace of rationality, when one might judge otherwise? The answer merely follows the realization that, no one, when in Osmo's shoes, could have been entirely persuaded by arguments, as long as he was contemplating his future accurately described in the book about his life. It doesn't matter if, intellectually, through painstaking philosophical scrutiny, he concluded for no-fatalism. As long as he could not avoid the facts described in the book, he would tend to base his conduct on quietism.

Interestingly, this scenario contrasts precisely with what usually happens to other philosophers, who meanwhile opt for fatalism: the philosopher who found himself in a position to conclude for any kind of fatalism would always have the emotional or psychological conduct of someone who is able to decide, deliberate and act. Osmo, however, would tend to be quietist in his attitude. A quietist attitude would be, for example, to never collect a debt, if the book about his life presented as a *fait accompli* that such debt would never be paid. A fatalistic philosopher would hardly have a different attitude from that he thought could interfere with a course of events.

Some philosophers' fatalism is an "armchair attitude", only intellectually adapted. The majority of attitudes outside the philosophical environment betray an intricate system of libertist beliefs, no matter how vehemently is concluded that there is no free-will. Due to the peculiarity of his life, only libertism could be Osmo's armchair attitude.

Shouldn't there be a harmony between what we are able to conclude philosophically and what a philosopher would then put into practice? Note that one of the compelling forces in Osmo's story is lost, if you consider that he might have a quietist attitude while not being a fatalist. Now, Osmo's attitude seems to be related to the conclusion that the world is a fatalistic one. But if it is possible that both things are independent, then it is possible to rationally reject fatalism, even when its appeal is very strong.

Voltaire reflected at length on the subject of determinism *vs* free-will. This Enlightenment man noticed, in more than one occasion, that human beings may not conceive themselves as free, since philosophical reflection may lead to that conclusion. Meanwhile, their behavioural and belief systems presuppose freedom. The fatalistic metaphysician is

the same person who will act as if free-will was the most natural of faculties. That is what we see, among other things, in the final paragraph of the chapter on human freedom, in the *Elements of the Philosophy of Newton* (1996, [19]), whose ideas its author summarizes in the poem *Discourse in verses on Man*, of 1738:

> *Vois de la liberté cet ennemi mutin,*
> *Aveugle partisan d'un aveugle destin;*
> *Entends comme il consulte, approuve, délibère,*
> *Entends de quel reproche il couvre un adversaire,*
> *Vois comment d'un rival il cherche à se venger,*
> *Comme il punit son fils, et le veut corriger.*
> *Il le croyait donc libre? Oui sans doute, et lui-même*
> *Dément à chaque pas son funeste système ...*
>
> (Voltaire, 1973, [18, p.218]).

For the philosophers of Enlightenment, especially when in contact with English Enlightenment,[21] to think of determinism as an aspect of the world was practically a natural conclusion. Though nothing in his attitudes would betray it. Something in human actions is imbued with the feeling of freedom in such a way that the most formal of demonstrations and the most proficient philosophical reasoning are useless by comparison.

The same is true of Osmo. His life has what we might call the "phenomenology of fatalism". As it happens, such phenomenology is not subject to revision through the consideration of philosophical arguments. We have a phenomenology of freedom and, as Voltaire thought, even if our philosophical conclusion on ultimate reality is not favorable to it, we are still creatures of habit, subject to intimate convictions. In the case of Osmo, the illusion of fatalism would be greater than the force of non-fatalistic arguments. Given his unusual situation, he could not avoid acting as a quietist. But Osmo's quietism bears little importance on any general metaphysical conclusions. After all, to conclude that the world is fatalistic because Osmo does not feel free is as unjustified as it would be for the French philosopher to conclude by free-will merely on the basis of what a man feels.

[21] English Enlightenment was influenced by Newton's discoveries.

7 Conclusion

Osmo, who would hardly exhibit a behaviour revealing it, might not be a fatalist. There are sufficient *defeaters* for important premises of fatalistic arguments that could persuade him, at least intellectually. Despite the existing tension between Osmo's behaviour and his possible adherence to libertism, that tension is acceptable and explainable. The rhetorical element added while fathoming the character's psychology merely makes the fatalistic argument more colorful, without not reinforcing it at all, and replies to fatalism are able to keep us away from the fatalistic conclusions motivated by Osmo's case. If Osmo had been a good philosopher, he too would be able to understand it, even in his strange condition.

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The Prior Internet Resources 2017: Information systems and development perspectives

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Abstract

The Prior Internet Resources (PIR) are presented. Prior's unpublished scientific manuscripts and his wast letter correspondence with fellow researchers at the time, his Nachlass, is now subject to transcription by Prior-researchers worldwide, and form an integral part of PIR. It is demonstrated that the PIR, defined as the virtual space delimited by the three content areas and Internet domains: 1) Priorstudies, 2) Prior Virtual Lab, and 3) Nachlass), contains six information systems of five distinct types. The informations systems are grouped into a "Transcriber Loop" to illustrate how unpublished material from the archive boxes goes through a transcription process to end in the Nachlass. A box taxonomy defines the transcription project's hub. Together with the "Transcriber Loop" this setup makes it possible to use the boxlists in conjunction with a Prior-bibliography also in PIR as a showcase to announce what is still in the archive waiting to be transcribed.

Keywords: A.N. Prior, Indexing, Information systems, Databases, Text repository, Archives, Taxonomies, Collaboratories, Research collaboration, Transcription, Virtual Lab, Correspondence

1 Preliminary remarks

The current description of the Prior Project[1] and the formulation of its goals have a strong focus on the dissemination of research done in this area to a wider audience of scholars, to make Prior's unpublished works as well as his manuscripts and letters, accessible for a larger audience of Prior researchers, promoting the project group's research activities and, last but not least, make the legacy of Arthur Prior known not only in the academic sphere, but among interested laymen and intellectuals as well.

Arthur Norman Prior who lived from 1914 to 1969 is today known as the founder of modern temporal logic and the person who secured this discipline as a theoretical subject within philosophy, theology, and mathematical logic. And more recently in computer science as well.

Prior came from New Zealand. He had been to Europe in the years leading up to the 2nd World War, mainly interested in theological issues, a path he pursued in the first years after the war, gradually turning his interest towards philosophy and logic. In 1956 he was the Visiting John Locke lecturer in Oxford, which meant a professional break through for him, and in 1959 Arthur Prior and his family moved to Britain for him to continue his academic career, first in Manchester as professor of philosophy, and finally in Oxford as a Fellow of Balliol College and Reader at the University of Oxford. At the time of his death his wife, historian Mary Prior sorted his archive of written material and bestowed it to the Bodleian Libraries in Oxford, where it can, with the approval of the library, be accessed and with respect to digitisation photographed, thus building the foundation for the "Virtual Lab for Prior Studies" to be described in the following within the setting of information science.

The Danish Prior websites, described and discussed in more detail in the following, will play a major role in these mediating endeavours. Sections two through five of this paper present and identify the content elements on these Internet sites, their structure, cohesion and more. In the final section we present some of the most obvious development perspectives, which can be envisaged from the preceding analytical results. Our theoretical perspective both on description and development

[1]This paper is based on research in the project "The Primacy of Tense: A.N. Prior Now and Then", funded 2016–2019 by the Danish Council for Independent Research – Humanities. DFF-FKK Grant-ID: DFF – 6107–00087.

of the Prior websites and implementation of innovations stems from information science theory and practice [40, 5], in particular the notion of an information system will be of great heuristic value in the outset of the study. We firmly believe that information science and the paradigm of library science, with which it is strongly associated [45], provide the necessary tools and framework for understanding Internet-based knowledge organizing, searching and retrieving systems such as represented in the Prior websites under consideration.

2 Overall structure of the Prior Internet Resources (PIR)

As a convenient umbrella term, we use "Prior Internet Resources" (PIR) for all the Danish Internet resources on Arthur Prior associated with our project. This term includes both formal digital elements such as websites, knowledge organizing units such as bibliographies and other information systems, which we discuss in length below. The overall structure of PIR comprises three main content components. "Foundations of Temporal Logic - The WWW-site for Prior-studies" [24], abbreviated "Priorstudies", is the main gateway for scholars interested in Arthur Prior's work and life. The related "Virtual Lab for Prior Studies" [1], in the following abbreviated as "PVL" ("Prior Virtual Lab"), is the virtual platform for researchers transcribing Prior's hand-written documents. Finally, we have the so-called "Nachlass", a full text archive of transcribed and published Prior manuscripts. These three distinct content areas, Prior Studies, PVL and the Nachlass, the three main parts of the information structure in the PIR, are distributed over three Internet domains, shown in Figures 1, 2, and 3, their URLs are:

- http://www.priorstudies.org/ (Priorstudies)
- http://research.prior.aau.dk/ (Prior Virtual Lab)
- http://nachlass.prior.aau.dk/ (Nachlass)

For the user, the key to the Danish digital world of Arthur Prior is Priorstudies, with links to both the PVL and the Nachlass.

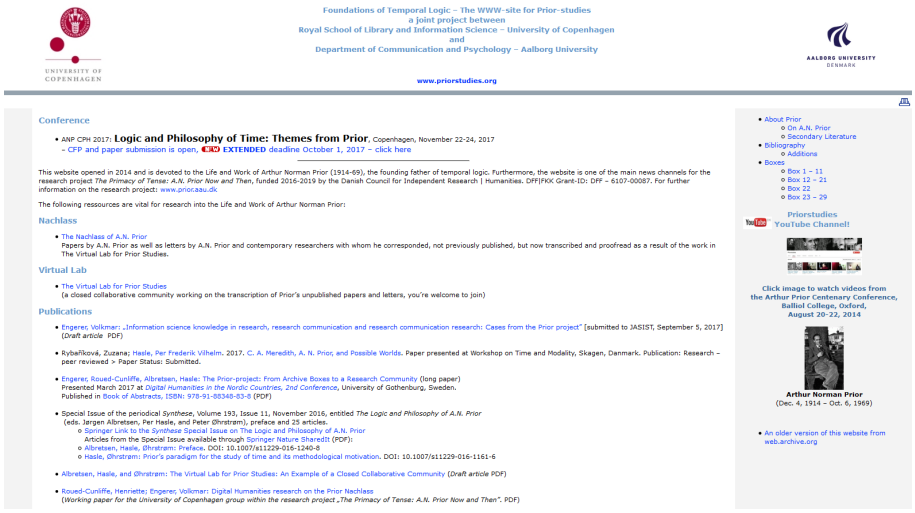

Figure 1: "Priorstudies", http://www.priorstudies.org/, screen dump, September 21, 2017, upper section.

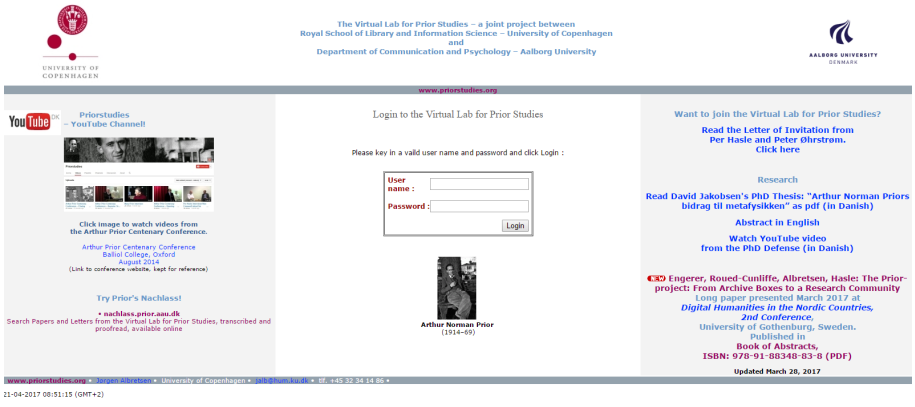

Figure 2: PVL ("Prior Virtual Lab"), http://research.prior.aau.dk/login_user.php, screen dump, April 21, 2017.

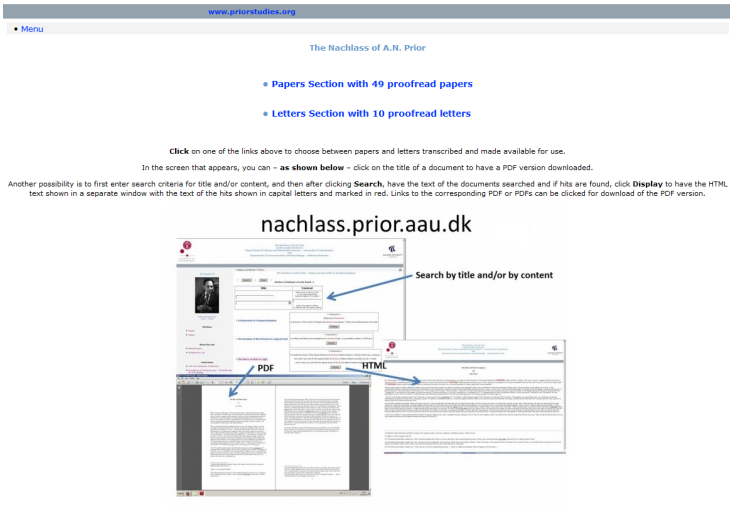

Figure 3: The so-called "Nachlass", http://nachlass.prior.aau.dk/, screen dump, September 21, 2017.

3 Information systems in general

We intend to analyze these three domains in terms of information systems, not in Internet domains or websites, which carry information only in a technical sense; information scientists therefore prefer to think in "information systems." Though the term 'information system', having its roots in the world of management and business [17], as default seems to refer to IT-based support for organizations to accomplish specific tasks [44], definitions and conceptions of information systems vary significantly between technology, social, socio-technical, and process views, as has been shown in a thorough review of information systems definitions [11]. The perhaps broadest, but still meaningful characterization of an information system stems from Wikipedia, a definition which is cited widely both in textbooks [13] and on websites of dubious engineering conferences, for example http://icic-aptikom.org/2017/2017/04/03/information-system-2017/. In the Wikipedia article itself no references are given. According to this definition "An information system [...] is an organized system for the collection, organization, storage and communication of information. More specifically, it is the study of complementary networks that people and organizations use to

collect, filter, process, create and distribute data." (Wikipedia, 21 April 2017, https://en.wikipedia.org/wiki/Information_system).

This broad and encompassing definition of information systems is practical and allows in a first step to identify six information systems embedded in PIR. We have marked each information system in PIR with the specific information-related action, taken from the definition above:

1. "Foundations of Temporal Logic - The WWW-site for Prior-studies": ... *communication of information* ...
2. Works written by Prior, primary literature: ... *collection, organization of information* ...
3. Works written on Prior, secondary literature: (*same as* 2).
4. "Nachlass" (full text): ... *organized system for the collection, organization, storage, and communication of information* ...
5. "Nachlass" in the archive boxes: ... *organization of information* ...
6. "Prior Virtual Lab": ... *complementary networks that people and organizations use to collect, filter, process, create and distribute data* ...

In information science, information systems are of several distinct types, most prominently documentary languages implemented in Knowledge Organization Systems (KOS) such as classification systems, thesauri, and ontologies [40, 27, 29], information services such as bibliographies, retrievable databases, and text repositories, and, last but not least, research portals, and collaborative academic platforms in general. In order to access information scientific characterizations of the 6 PIR-embedded information systems these systems have to be mapped on more specific types such as the ones mentioned. The goal with this exercise is to draw systematically on relevant and useful information scientific disciplinary wisdom, which improves our understanding of PIR and can be a professional starting point for developing and improving the present PIR.

PIR, defined as the virtual space delimited by the *three* above-mentioned content areas and Internet domains (Priorstudies, PVL, and Nachlass), contains after a first inspection *six* information systems of *five* distinct types. All information systems are well known and acknowledged in the information scientific research tradition:

1. "Foundations of Temporal Logic - The WWW-site for Prior-studies" /research portal (part of the Priorstudies Internet domain) [6, 22]
2. "Of Prior"/bibliographical database, works written by Prior, primary literature (part of the Priorstudies Internet domain) [19,

25]
3. "On Prior"/bibliographical database, works written on Prior, secondary literature (part of the Priorstudies Internet domain)
4. "Nachlass" in its narrow meaning/full text database, text repository (Nachlass Internet domain)
5. "Nachlass" in the archive boxes/taxonomic entry to archival metadata (part of the Priorstudies Internet domain)
6. Prior Virtual Lab/collaboratory, research platform (Prior Virtual Lab Internet domain)

This digital informational structure of PIR, and the way these information systems are connected with each other, can now be visualized as shown in Figure 4.

4 PIR's 6 information systems

In what follows, we will go through these six systems, give a basic information theoretic description of each, and based on this identify possible development steps and improvements.

PRIORSTUDIES: A RESEARCH PORTAL (1)

Priorstudies has a typical, though a bit outdated research portal outlook [6]. It provides information on the site's main authors, general information about Prior and scattered news on Prior-related publications and conferences on the front page.

More theoretically, research portals are regarded as "Internet-based knowledge management instruments" which serve as platforms for exchanging ideas in research communities in a structured manner [6]. Knowledge management is typically seen as an enterprise's or organization's activities of representing, storing, and disseminating corporate knowledge [6]. However, knowledge management touches also on other organized settings such as academic research communities [6]. In particular this is true for research portals, which enhance a research community's internal communication and thereby contribute to "virtual communities of practice" [6]; research portals can also be directed to an external audience, to which research information is disseminated [6]. More schematically, research portals can be organized by a research topic or a specific person, the latter is the case with the PIR; other

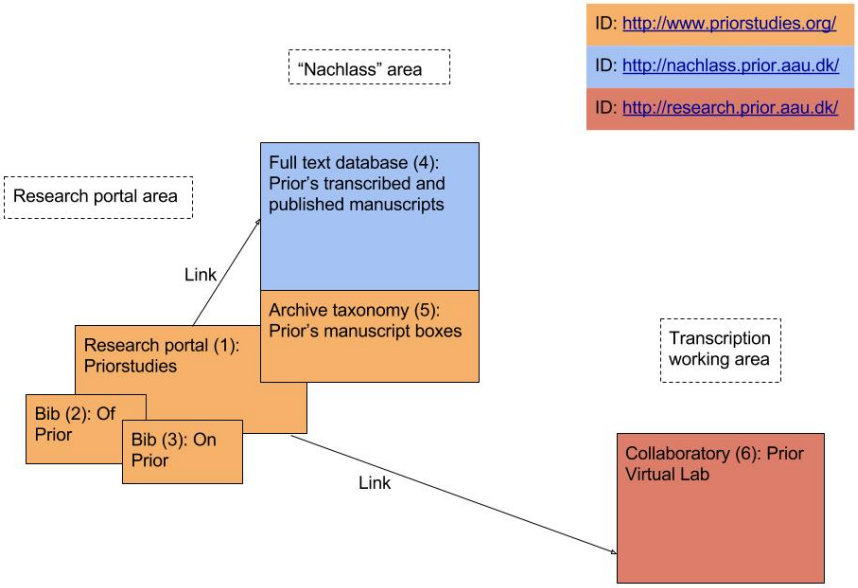

Figure 4: General structure of PIR: *six* information systems representing *five* distinct types, implemented on *three* Internet domains functioning in three areas.

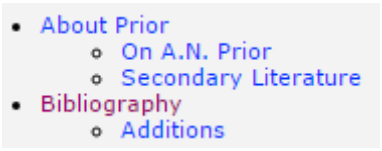

Figure 5: Link section in Priorstudies, directing the user to the bibliographies, screen dump, May 19, 2017.

portals are delimited geographically or by institution [6]. This preliminary list of insights from knowledge management directs the attention, for instance, to the connection and the dynamics between explicit and tacit knowledge in a community/organization [35]. Another issue, brought into the forefront by knowledge management, are reflections on the availability of knowledge (internal, external, or to be created by research), to reach out after the "correct" recipients, the willingness of knowledge producers to share their knowledge and questions of accessibility in general [40].

Embedded in Priorstudies (in the same Internet domain) are two relevant types of information systems [28, 32, 34, 40], which are of particular information scientific interest: traditional bibliographical databases and a collection of archival metadata on unpublished handwritten material by Prior. In addition to that, Priorstudies provides a link to the Nachlass domain, which hosts a full text database of transcribed handwritings by Prior. The last two items, the archival metadata and the completed transcriptions, are by project insiders often referred to as the "Nachlass".

OF/ON PRIOR: BIBLIOGRAPHICAL DATABASES (2/3)

The bibliographic part of Priorstudies includes a chronologically ordered list of Prior's published works (bullet "Bibliography" in Figure 5) and a register over literature on Prior arranged according to four material types/genres, i.e. books/journal articles, reviews, obituaries, and memoires (bullet "Secondary Literature" in Figure 5).

From the point of view of information science, both bibliographical bases lack advanced search options, as none of the two resources offers search facilities beyond the browser's built-in web page search [18]. Taking a web interface design perspective, a more visible link to "Bibliographical resources" in the navigation bar would help to direct the user to these two bibliographies; bibliographies are an established and central category in information and library science [15] and still known and well-esteemed by many expert users. Last but not least, current approaches to linked data [40] and mashups of information services on one website [7, 33] give rise to enrich and update the existing two bibliographical lists by dynamic external links to quality resources from the domain, for instance The Philosopher's Index.

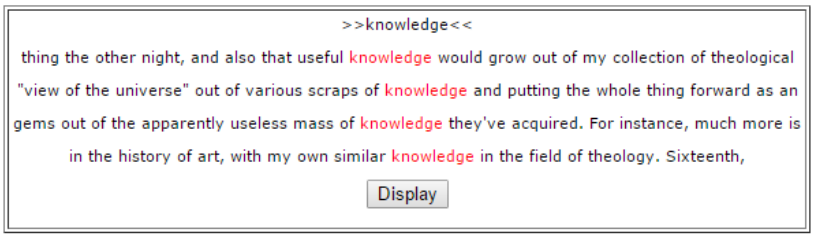

Figure 6: A search with "knowledge" in the Nachlass, full text repository, screen dump September 21, 2017.

THE FULL TEXT NACHLASS: A TEXT REPOSITORY (4)

The full text part of the Nachlass (http://nachlass.prior.aau.dk/) is situated in a separate web domain and includes at the time of writing transcriptions of 49 papers and 10 letters by Prior, all downloadable as pdf-documents. The system offers full text searches in the transcribed documents and lists for each document all occurrences of the search term in a one line linguistic context with the search term in the middle of the chain. An example with the search output for the term "knowledge" is shown in Figure 6.

Clearly this concordance-like mode of presentation of search results is based on the KWIC index principles (**k**ey**w**ord **i**n **c**ontext index), where a significant search term in a document title is presented not in isolation, but is surrounded by the other content words in the title. This technique is described as a post-coordinating information retrieval tool which is, to a large degree, dependent on the quality of the collection's texts, and their linguistic and stylistic features [39]. However, since "[...] computerized full text search became common [...]" [46] KWIC indices are largely outdated as a tool of its own. In the Nachlass, however, the KWIC is used as an easy entry to decide if the whole text seems interesting. The full text with the search term highlighted and in all caps opens in a separate window by clicking on the Display button shown in Figure 6. An example related to the search in Figure 6 is shown in Figure 7.

The full text part of the Prior Nachlass is important because it not only presents the results of the collaborative transcription work done in the PVL to a broader audience of philosophers and logicians in the field, but also documents the large work done by the Prior project's par-

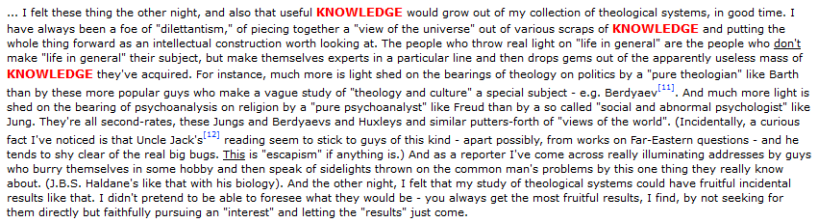
... I felt these thing the other night, and also that useful KNOWLEDGE would grow out of my collection of theological systems, in good time. I have always been a foe of "dilettantism," of piecing together a "view of the universe" out of various scraps of KNOWLEDGE and putting the whole thing forward as an intellectual construction worth looking at. The people who throw real light on "life in general" are the people who don't make "life in general" their subject, but make themselves experts in a particular line and then drops gems out of the apparently useless mass of KNOWLEDGE they've acquired. For instance, much more is light shed on the bearings of theology on politics by a "pure theologian" like Barth than by these more popular guys who make a vague study of "theology and culture" a special subject - e.g. Berdyaev[11]. And much more light is shed on the bearing of psychoanalysis on religion by a "pure psychoanalyst" like Freud than by a so called "social and abnormal psychologist" like Jung. They're all second-rates, these Jungs and Berdyaevs and Huxleys and similar putters-forth of "views of the world". (Incidentally, a curious fact I've noticed is that Uncle Jack's[12] reading seem to stick to guys of this kind - apart possibly, from works on Far-Eastern questions - and he tends to shy clear of the real big bugs. This is "escapism" if anything is.) And as a reporter I've come across really illuminating addresses by guys who burry themselves in some hobby and then speak of sidelights thrown on the common man's problems by this one thing they really know about. (J.B.S. Haldane's like that with his biology). And the other night, I felt that my study of theological systems could have fruitful incidental results like that. I didn't pretend to be able to foresee what they would be - you always get the most fruitful results, I find, by not seeking for them directly but faithfully pursuing an "interest" and letting the "results" just come.

Figure 7: Part of the full text with hits highlighted and search term in all caps. The text in question is the "Diary Entry March 25, 1942", one of the texts in the Nachlass, screen dump, September 21, 2017.

ticipants during the last 10 years in photographing and thereby making accessible the almost forgotten contents of the archive boxes in the Bodleian Libraries . This full text information system deserves therefore special attention. Information scientific insights can provide increased visibility or better accessibility of the full texts documents for Internet search engines and crawlers [31], among that an encoding of database documents in formats, which will make them readable for other programs and Internet services etc. More traditionally, a library and information science inspired approach can give rise to an extended metadata structure with a controlled indexing and search vocabulary aligned to the terminology of the Prior research community. A classification could be taken in account as well, where current tempo-logical thinking and categorizing is reflected. Last but not least, a search interface which corresponds to Prior researchers' specific information seeking behaviour would be desirable.

PRIOR'S MANUSCRIPT BOXES: AN ARCHIVE TAXONOMY (5)

The second part of the Nachlass is constituted by archival metadata on unpublished handwritten material by Prior. In a taxonomy-like manner [5, 4, 14],[2] access to the metadata is organized in box categories, repre-

[2]Note the varying use of the term 'taxonomy'. The mainstream concept seems to be adopted in King, Reinold [30] as elaborated in Bawden, Robinson [5]: In this view, taxonomies are classification-like KOS [4] which are designed in terms of the system's context of use and the amount of information to be organized. A taxonomy is shaped by the "local" culture and needs and behaves rather liberal in the light of the strict classification rules. Taxonomies mirror the specific interest of the hosting organization and give access to quite different types of materials, for instance databases, e-mails, docu-

senting the actual physical boxes where the written documents originally have been stored (and still are) at the Bodleian Libraries in the UK. Links to the individual boxes take the user from the hierarchy's top (a pragmatic archive-specific order principle) to the next subordinate levels of the taxonomy providing descriptions of the particular box contents. In the case of correspondences, for instance the second-level organization is realized grossly by the category of the sender name. Under each correspondence category a hybrid collection of informal, grossly unstructured metadata is presented, all having strong potential to enter into a more systematic metadata structure. As an example box 1, correspondence 1 (Prior-Anderson), is chosen:

- ◇ Conventional indexing category: "Abstract" [40, 19], representing summaries of the contents of correspondence 1 as a whole:
  - *This comprises 68 letters from Alan Ross Anderson (ARA) to Prior, dated from 28.06.1955 to 03.03.69; and 88 letters from Prior to Anderson, dated from 21.06.1955 to 12.02.1969.*
  - This formulation gives rise to the question what the proper object for indexing should be: individual letters or larger entities defined by the set of letters written by person A to B in a time period t1, and B to A in a time period t2, where t1 and t2 practically overlap completely, as the abstract-like archiver formulation above suggests. And, more important, how do we grasp and model the interactive cohesive structure of letters following each other on the timeline and referring to each other? What constitutes a "complete correspondence"?
- ◇ Half-conventional indexing category: "Archiver comment" (there is a parallel to standard fields in library catalogues where the cataloguing instances often themselves encode library internal information such as acquisition date). What we have here are signed comments with three preceding hyphens (what could be interpreted as a formal marker of this field type), in which the archiver refers both to whole correspondences and smaller items, and gives additional information, not contained in the indexed letters themselves:

ments, people. A rather specialized concept of taxonomy can be developed in terms of semantic relations between a hyponym and its hyperonym. This formal position is for example taken by Stock [40], referring to Cruse [21]. We use the term in accordance with the more liberal views on taxonomies attested by the first group of authors.

- *Lecture Notes for courses given in the University of Chicago, early 1962, when ANP was a Visiting Professor there. — Per Hasle.*
- Such notes construct often links to other documents:
- *Probably draft of* (1966a)*, which was meant as a part of 'PPF'* (1967a)*, but arrived at the publisher too late for inclusion. — Per Hasle.*
- This linking gives the prerequisites for a relational structure in a document network implemented in bibliographical databases.

◇ Non-standard indexing category: "Document archive history". This field typically contains information about the prehistory of a letter, and how it made its way to the box:

- (*The copies of letters from Anderson to Prior were sent by Anderson to Mary Prior not long after ANP's death.*)
- Why is this field regarded distinct from the more conclusive category of Archiver comments? An argument for this could be the consequent use of typographical means (brackets) and the lack of a personal signature, which is a formative attribute of Archiver comments. In this sense a Document archive history is part of the "formal", descriptive metadata [5, 39, 31], signifying objective properties of the archived item. Archiver comments are then, as the distinction implicitly suggests, of a more subjective character.

Other hints on potentially user-relevant indexing fields (and retrieval algorithms) are remarks as the following:

> *The correspondence falls, temporally as well as content-wise, into three major groups:* [...]

This suggests the entity of a "Correspondence section": As correspondences essentially are dialogical sequences, the notion of a formal 'correspondence', solely defined by a particular sender and recipient in a certain stretch of time, must be broken down in adjacent, timely coherent (continuous communication, without larger interruptions) and topic-centred communication sequences. This is what the archiver in my reading suggested in the above remark. Other candidates for indexing fields in an adequate metadata structure for Prior's correspondences are domain-specific subject descriptors [4, 8, 41], for example terms for the logic theory discussed (Q-system, Q-predicate, ...), the

logical branch being addressed (deontic logic, ...), the private/non-private character of the letters, and, importantly, other works, both Prior's and of other logicians and philosophers, which are being touched upon in the letters. Methodologically, formal and machine-readable fields must be extracted from the existing annotations, which are informally in character and produced by a domain specialist on the field; this can possibly be achieved by a sort of text analysis. The goal of this exercise is an equivalent, but formal record structure.

THE PRIOR VIRTUAL LAB (PVL): A COLLABORATORY / COLLABORATION PLATFORM (6)

The PVL is a closed online platform where Prior-scholars can access photographs of the original box papers in order to transcribe and comment them. After transcriptions have been completed, they then run through a peer review process and are published in the full text section of the Prior Nachlass (information system 4). The direct incentive for scholars to undertake this task is to achieve credit for a scholarly, peer-reviewed text edition, which is published and accessible for all. More indirect incentives for researchers can be the opportunity to discover hitherto unknown material, to boost one's research through unique text references and primary material, or simply to collaborate with other scholars in the same domain of research. A sometimes underestimated and potentially motivating factor is the deep learning effect which arouses from the intense cognitive text work demanded by transcribing. This effect is not yet attested, but could easily be put to the test in the project group.

The PVL can in more general terms be characterized as a "collaboratory". This expression has been used since the 1980ies [23] for computer-aided scholarly collaboration environments and refers to online organization units which compensate for physical distance, promote interaction and contacts between scholars in a common area of knowledge and give access to data and text sources, artifacts, and virtual tools necessary for dealing with complex research tasks [12]. Technology in research collaboratories links therefore researchers with other researchers, researchers with information and with tools [23]. In Bos' et al. [12] study seven types of collaboratories are differentiated; hereunder instrument sharing communities (for example telescopes), data systems (for example the protein database) or virtual learning communities. In the

framework of this classification the PVL falls under type 2, *Open Community Contribution System* (OCCS). An OCCS collects from geographically spread individuals their contributions to a joint research problem. These contributions consist of work, not of data or information [12]. An OCCS does not gather established and permanent research teams, but the participant basis is more open. As Bos et al. [12] mention, quality control of the individual contributions can be a specific challenge for this type of collaboratory. In the PVL systematic refereeing exerts this quality control. Other types of collaboratories which in one way or another can inform the development of the existing PVL are Virtual Communities of Practice (network of scholars sharing a field of research) and Virtual Learning Communities [12].

Collaboratories can have positive effects in a whole range of areas, hereunder science itself (productivity and research production, breakthrough discoveries, ...), researchers' careers and attraction of younger talented researchers, learning and mutual inspiration, development of novel virtual tools, infrastructures and more [36]. In terms of which factors determine the success of a collaboratories Olson et al. [36] identify four clusters of components:

a) organization of work to be done in a collaboratory,
b) common ground between the participants,
c) the participants' readiness to collaborate, and
d) project management and use of technology.

With respect to a) the authors emphasize that tasks have to be clearly defined without demanding frequent communications as "tight coupling"; reciprocal interdependence between participants belongs to the factors which make it difficult to overcome distance [36]. The PVL with its clearly defined task – transforming pictures of text to machine-readable text and providing this text with comments if necessary – fosters a rather isolated workplace setting where a lonesome transcriber engages with a silent and deaf text. But this is not necessarily so; the work of transcribing can be done in collaborating teams, without creating mutual dependence on other collaborators, where different views often lead to better results than one person alone could have achieved [43, 3, 38]. Similar can be said with respect to different kind of tools and information sources (encyclopaedias, web information services etc.) which can be helpful in solving difficult tasks in the "lonesome" part when the transcriber is struggling with the text. A transcriber's interaction with

research tools "at hand", where and when a certain question or problem arises, is important and these aiding sources should be available in the working platform and be ready at hand when needed.

With regard to b) it is important that researchers in a collaboratory share some mutual knowledge, believes and assumptions, which typically are tacit and unexpressed, but presupposed by interacting individuals in normal conversation [23, 36]. This presupposed "common ground" [37, 20, 16] is difficult to achieve and maintain in a virtual research environment, where scholars, who often do not know each other personally, come from different knowledge domains and lack a common vocabulary. Controlled vocabularies such as concordances, dictionaries and explicit explanations and instructions are one way to support common ground. These vocabularies can then, as Olson et al. [36] observe, be used in information retrieval services implemented in the collaboratory. Another aspect that is tightly linked to the common-ground problem is to design communication technology in collaboratories in a way that compensates for the lack of a common setting - in other words, the creation of trust has to be "implemented" as distance matters [23, 36, 37, 9]. The PVL is, on the one hand, a homogeneous enterprise, where only domain specialists (logicians and philosophers with interest in time) with a rather common scholarly background can have a part in. On the other hand, diverse cultural and linguistic provenances, age differences and different grades of domain expertise will often have the consequence that there is only little common ground for participants to rely on. Common ground is certainly an important feature of interactivity relations, which has to be considered in designing adequate communication fora and channels for PVL participants.

Point c) refers to participants' motivation to collaborate and whether they feel themselves sufficiently equipped to execute the task. Here social and psychological aspects come into play such as participants' positive attitude to collaborate, rewards and benefits connected to collaboration or aspects of trust [36]. This is certainly one of the more critical areas of the PVL. At the time of writing, we know very little about whether transcribers want to collaborate with others, and if need be, which kind of collaboration they would prefer. Furthermore we can say nothing about which tools they eventually lack. It seems obvious that incentives for collaboration activities have to be implemented such as a hotline in case the transcriber is stuck in the process or a help forum

where specialists in Prior's handwriting assist less trained transcribers.

The last point d) mentions effective knowledge management which has to ensure that data are stored in reliable and compatible formats (data migration), acknowledge users' needs in technology and implements the software that is needed for participants to do their job [36]. After our discussion of Priorstudies as a research portal in the outset of this paper, we here address knowledge management again. Evidently, research portals and collaborative platforms such as the PVL have much in common, but they focus on different goals of the information system which underlies them: whereas research portals typically are directed to an external audience, to which research information is disseminated [6], the PVL is as a collaboration platform of the type *Open Community Contribution System* (OCCS) oriented inwards and directed towards the internal contribution consisting of cognitive labour [12]. But the same principles in organizing knowledge and information are at work in both spheres.

Again, this point demonstrates the importance for the PVL to acquire more knowledge about the lab's users, to shed light on their attitudes to technology and collaboration, find out how good they are in using collaboration technology etc. Then it can be decided which measures must be taken in order to support transcribers in their work and enhance their possibilities to collaborate with others.

5 The "Transcriber Loop"

For the PVL to work, and to transcribe, digitize and make electronically accessible (findable, searchable, shareable, ...) as many unpublished manuscripts of Prior as possible on the Internet, the dynamics between the Archive taxonomy (5), the PVL (6), and the Nachlass' full text database (4) is crucial. In this configuration, the box taxonomy from the Nachlass section (5) is of particular relevance, as it functions for Prior scholars as their only possible point of departure in order to identify relevant topics in the original hand-written material and match these topics with their own research questions or research interests. It is important to note that researchers at this point in their inquiry do not have the opportunity to verify the documents' relevance by consulting the original through an electronic copy, here a photography [10]; it is solely the documents' metadata, their descriptions or representa-

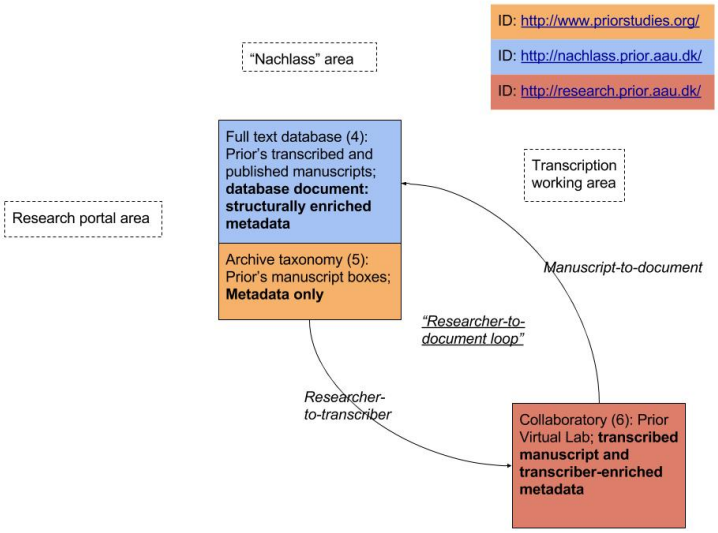

Figure 8: The Researcher-to-document loop connecting three information systems in PIR

tions, which must be taken at face value as constituting reliable surrogates for the original document by the researcher. A preliminary match of interest is certainly a major motivation for scholars to engage in signing up in the PVL, requesting the copy and then determining whether it is worthwhile transcribing. In other words, if Prior-scholars cannot in a trustworthy way ascertain whether the Nachlass contains relevant documents with regard to their research questions, it is highly unlikely that they will proceed and register for the PVL. The box taxonomy must therefore be viewed as the transcription project's hub, where the researcher kicks off a vital document circle which takes its starting point by the researcher identifying an appropriate document for transcription; is this successfully completed, the document runs through its transcription and returns finally to the Nachlass as a full text searchable electronic document and database record. We have illustrated this dynamics in Figure 8, where the pathways of researchers and manuscripts / documents between the three information systems are schematically sketched.

As depicted in Figure 8, the researcher turns into the role of a tran-

scriber by moving from the Archive taxonomy to the PVL. In this transition the formal manuscript metadata, originating from informal expert descriptions as demonstrated in subsection 4, remain attached to the manuscripts throughout the subsequent phases of information processing. In this initial phase of the manuscript circle, the "manuscript-born" index fields, which have been derived and reformulated from the specialist archiver's descriptions, are as close to the original documents as they can be. This makes them extraordinary valuable access points [31, 26] for advanced specialist searches. As the researcher progresses to the PVL, taking on the role as a transcriber, he/she does not only carry out the transcription, but also enriches the manuscripts metadata from the archive by information from his/her expert knowledge and special textual knowledge arising by his/her deep involvement in the manuscript contents at the time of transcribing. This is one aspect of the manuscript-to-document process, indicated by the arrow from the PVL to the Nachlass full text database. Metadata enrichment, as it happens here, is a typical case of 'enrichment via informational added values', where texts are further formally described and indexed for content [40], resulting in fully-fledged surrogates, sometimes called 'documentary units' [40]. The last step of this manuscript-to-document process is the formal adaptation of documentary units to a database environment, an organized collection of surrogates which can be searched, retrieved and explored. This makes them to what often is called a 'record'. From this information science perspective, the manuscript-to-document arrow signifies a text's (manuscript's) change of status from a more or less unstructured and informal piece of text to a standardized record in a formal, machine-readable and searchable database collection in the full text Nachlass.

6 Development issues

A central issue to be considered is the importance of offering the Nachlass to as wide an audience as possible in a well-defined open access format. To this end, we have concentrated on the following points:

1. The texts must be encoded in standard TEI-XML as the end product. A possible layout of the bibliography in XML could be as shown in Figure 9. With this made, the texts in the PVL will be more easily accessible in future implementations, directed at the

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="bibliography-xslt-tei.xsl"?>
<root><!-- -->
    <row>
        <prior_bibliography_id>1413</prior_bibliography_id>
        <bib_id>Copeland_BJ_2002_035</bib_id>
        <source>Scopus</source>
        <sort_id>2002_035</sort_id>
        <author_first>B.J.</author_first>
        <author_last>Copeland</author_last>
        <add_authors></add_authors>
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        <published_year>2002</published_year>
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        <type>Article</type>
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        <publication_title></publication_title>
        <series_title>Journal of Philosophical Logic</series_title>
        <volume>31</volume>
        <pages>99-137</pages>
        <location>Philosophy Department, University of Canterbury, Private Bag 4800,
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        <publisher></publisher>
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        Journal of Philosophical Logic 31: 99-137</comments>
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        <regdate>20170302203526</regdate>
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        <editors></editors>
        <sub_title></sub_title>
        <url></url>
        <email>jack.copeland@canterbury.ac.nz</email>
        <work_cited>Prior_Arthur_Norman_1955 Formal Logic Clarendon Press Oxford |
        Prior_Arthur_Norman_1957 Time and Modality Oxford University Press Oxford |
        Prior_Arthur_Norman_1967 Past Present and Future Clarendon Press Oxford |
        Prior_Arthur_Norman_1968 Papers on Time and Tense Clarendon Press Oxford |
        Prior_Arthur_Norman_Logic modal 1967 The Encyclopedia of Philosophy P.
        Edwards ed. Macmillan New York | Prior_Arthur_Norman_Modality and
        quantification in S5 1956 J. Symbolic Logic 21 pp. 60-62 |
        Prior_Arthur_Norman_Possible worlds 1962 Philos. Quart. 12 pp. 36-43 |
        Prior_Arthur_Norman_Tense logic and the continuity of time 1962 Studia Logica
        13 pp. 133-148 | Prior_Arthur_Norman_The syntax of time-distinctions 1958
        Franciscan Studies 18 pp. 105-120 | Prior_Arthur_Norman_Three-valued logic
        and future contingents 1953 Philos. Quart. 3 pp. 317-326;</work_cited>
        <wos_ut></wos_ut>
    </row><!-- -->
</root>
```

Figure 9: An example of XML markup of an entry in the bibliography.

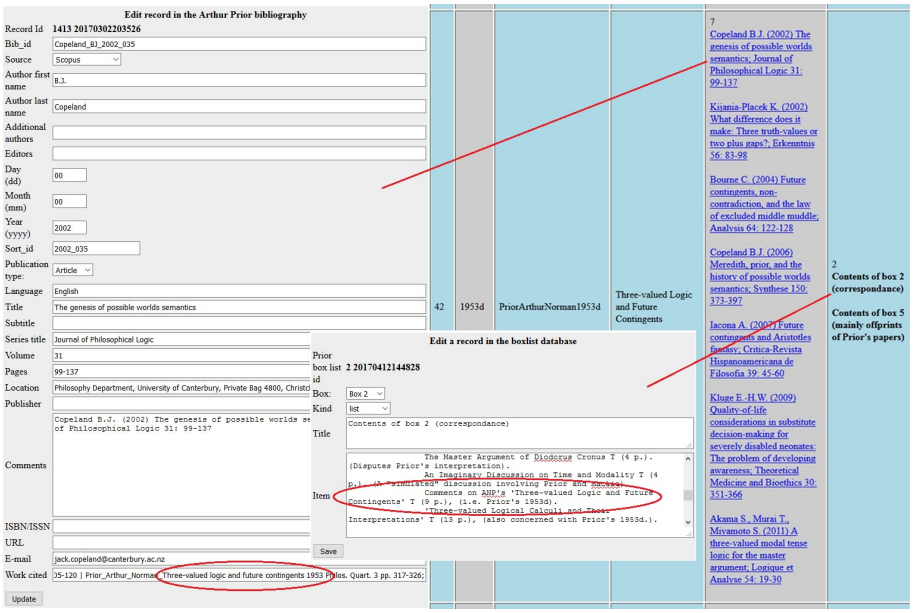

Figure 10: Cross-referencing bibliography with boxlists and citations, text in question "Three-valued Logic and Future Contingents", screen dump, August 18, 2017.

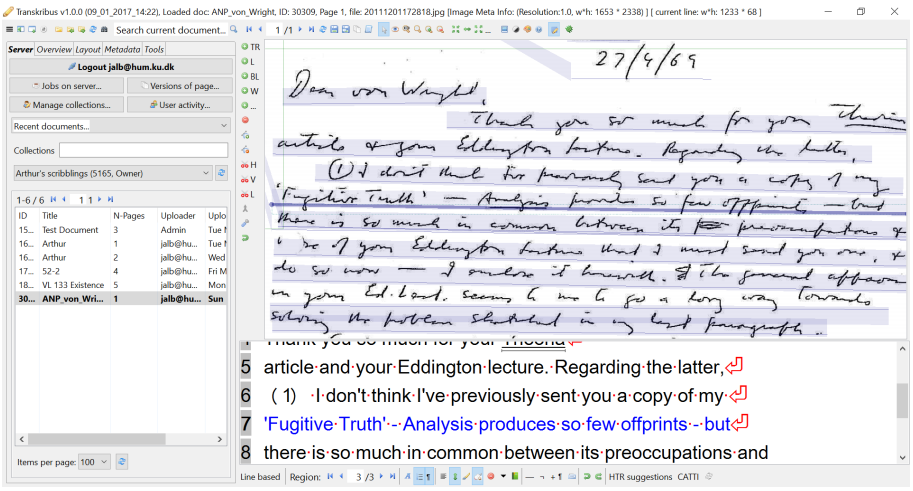

Figure 11: Transkribus interface training the system to recognise Arthur Prior's handwriting, screen dump, November 26, 2017.

open journal community.

2. The "Transcriber Loop" makes it possible to use the box-lists and bibliography as a showcase to announce what has been transcribed, verified, and accessible in the Nachlass. Due to the legal backdrop, that photos can not be made publicly available, these access points, as illustrated in the "Transcriber Loop" will show to potential PIR users what is still in the archive.
   A possible access point in the "Transcriber Loop" could be the linking of bibliography with boxlists, as shown in Figure 10. This to illustrate a typical issue within bibliometrics when dealing with research publications. The question could be "Why is a journal article from 1953 (*Three-valued Logic and Future Contingents*) suddenly cited frequently in the years 2002–2011, and what do the boxlists tell about the sources of this article. Furthermore, what parts of the material in the box have already been made available in the Nachlass, and what could be interesting among the remaining materials in the box for me as a researcher to sign up for transcribing in the PVL?"
3. Another path to explore is the possibility of doing automated recognition of the handwritten manuscripts within the Transkribus project [42] and use the text resources from this as a more convenient foundation for proofreading with an expected result to have more rapid additions of text to the Nachlass. The Transkribus system does however require a training set of manuscript pages, as shown in Figure 11, so the benefit to the current project could well be limited. The basic idea to have systems like Transkribus make access to text material easier must not be underestimated, and the PVL can easily be part of such an effort.

7 Conclusion: Visions for the future work

The PVL was at its conception in 2011 a forerunner of what now six years later is gaining interest as a research field of research communities on the web, within the project group behind the PVL often labelled a "Closed Collaborative Community". An important next step will be the streamlining of the PVL to adhere to recent developments within relevant fields of information science. The data underlying the PVL must be more separated from the interface, with the idea that the data set

is more targeted at the open access de facto standards APIs, and the interface can be reused in other settings. The whole PVL with its PIR makes a very integrated impression and has the potential to be the test bed for similar projects within Digital Humanities. An overall picture of the PVL and Nachlass with historical background and illustrations of its practical use can be found in [2].

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