The Forgetful World

A defence of presentism in light of modern physics

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Statement of Originality

To the best of my knowledge, the content of this thesis is entirely my own work. This thesis has not been submitted for any other degree or purpose. I certify that the intellectual content of this thesis is the product of my own work, and that all sources and assistance received in preparing it have been acknowledged.

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Abstract

The aim of this thesis is to defend a presentist metaphysics. I respond to a series of objections against presentism, including some that draw on our best physics. I also explore ways in which presentism might play an active role in interpreting and constraining physical theory, beyond merely being consistent with it.

A unifying theme of this thesis is that I advocate for a reduction of presentism to its bare essentials. Within the proposed ontology, reality is three-dimensional. *Time* only exists in the sense that three-dimensional reality primitively changes. I reject any temporal dimension, extension, or direction. I reject any primitively tensed facts or nonpresent-tensed truths. I also reject any notion of simultaneity, beyond the mere fact that multiple entities exist in the three-dimensional world. I accept and embrace that if ontology is 'stripped back' to the present, then other features of metaphysics that depend on ontology should be stripped back too.

The world, under this view, is a forgetful one. What we call the 'past' has been utterly lost from existence: there are not even any absolute *facts* or *truths* about how things once were. All that remain are records, memories, and the like, but there are no objective underlying truths to which those records correspond. This has implications for physics. In a forgetful world particles have positions, but no entire *trajectories*. The present may be certain and determinate, but the past and future are at best modelled using probabilistic mathematics.

I believe that the world is likely to be as I describe. I will not attempt to argue, however, that this view is *intuitive*. Instead I will argue that it can account for our experiences and observations, including those from physics, in a simple and effective way. Most importantly, I argue that this view succeeds in the face of challenges where other versions of presentism fail.

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Attributions

Three of the principal chapters of this thesis are adapted from articles written for independent publication. I am the sole author of all of these articles, which were written by me during the period of my candidature. I have made small changes to the text in order to improve the cohesion of the thesis, including for example the addition of cross-references between chapters. The articles included are:

Chapter 2: 'What Time is Not: Presentism as Three-Dimensionalism' currently under review by *The Philosophical Quarterly*.

Chapter 3: 'Hard Presentism' (2021) in *Synthese*, vol 198, pp. 8433-8461.

Chapter 4: 'Relativity and the Fickle Present' currently under review by *The British Journal for the Philosophy of Science*.

As supervisor for the candidature upon which this thesis is based, I can confirm that the authorship attribution statements above are correct.

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Disclosures

The author has no relevant disclosures to make in relation to animal or human ethics, intellectual property, or further assistance or editing in the writing of this thesis. All figures are my own, though I am grateful to Elise Morton for assisting me in composing the cover image.

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Chapter 1: Introduction

The central aim of this thesis is to defend a temporal ontology called presentism. Presentism is, broadly speaking, the view that only present things exist.[1] It is perhaps easiest to understand this view by considering the alternatives to it. A time travel story might depict the year 1955 as existing in the past, as a sort of *place* that one could in theory travel to, if only it were possible to retrofit a DeLorean in the right way. Presentists deny that such a form of time travel is possible, because they believe that there exists nowhere (or no-*when*) to travel to, other than this present that we already occupy.[2]

Presentism has faced a great deal of opposition. Some critics invoke our best science, arguing that modern physics favours other, rival temporal views, and at worst might contradict presentism outright.[3] Other objections do not draw upon physics, but rather stick to what might be called 'pure philosophy'. The critics argue that presentism runs afoul of internal logical inconsistencies,[4] or that it conflicts with popular views from other areas of metaphysics, such as truthmaking.[5] I will endeavour in this thesis to defend presentism from both schools of criticism: against physicists and philosophers alike.

I believe that presentism is true. I am uninclined to believe that presentism is *necessarily* true.[6] I do not think that other views are categorically incoherent or impossible, but on balance, presentism seems the most convincing to me.

[1] This wording is used by Markosian (2004, p. 1) and Ingram and Tallant (2018), among others. I will have much more to say about the definition of presentism in chapter 2.

[2] In §6.2 I discuss other forms of time travel that do not invoke multiple existing times. These might be compatible with presentism: see Keller and M. Nelson (2001) and Bernstein (2017).

[3] See for example Putnam (1967), Savitt (2000), Wüthrich (2013), and Rovelli (2019).

[4] This includes problems with *passage*, discussed by D. Williams (1951) and Leininger (2015), and also problems with *defining* presentism, summarised by Meyer (2005) and Deasy (2019b).

[5] See Keller (2004), Crisp (2007), and Caplan and Sanson (2011).

[6] Ingram and Tallant point out that 'although presentists sometimes make this move, there's very little discussion in the literature as to whether PAN [necessarily, presentism] is preferable to PA [presentism alone], and if so, what would justify that preference' (2018, sec. 1).

When weighing up the merits of competing temporal ontologies, I accept that it is crucial to consider what our best physics implies. Discoveries from physics can reveal important facts about the underlying nature of reality, including the nature of time.[7] If presentism is to be supported then it must be shown to be consistent with these discoveries. In this thesis I make such a defence, but also go a step further. I argue not only that presentism is consistent with established physics, but also that there is useful understanding to be gained by adopting a presentist approach to unsolved physical problems, such as that of interpreting quantum mechanics. Presentism is not merely a view that sits unscathed, once the physics is 'done'.[8] Rather, presentist thinking can play an active and contributing role towards our understanding of the physical sciences.[9]

Throughout this thesis I will assume a certain breed of ontological realism. I believe that there is an external world, existing at least largely independently of any given person or cultural group,[10] with one particular temporal structure (however complex that may be). My goal, and indeed what I regard as the primary goal in temporal metaphysics, is to describe the temporal structure of that single, actual, external reality.[11] Some readers might doubt this assumption, and reject that there is an 'external world' so conceived. It is not the purpose of this thesis to defend realism against such views. I merely seek to convince other ontological realists that external reality might be limited to the present.

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[7]Dirac (1978) argued that fundamental physics, and the mathematics contained within, should be the 'starting point' for ontology. My arguments do not go so far. Presentism is not generally *motivated* by physics, even it might be *consistent* or even *useful* in that context.

[8]Other defences of presentism tend to merely argue that it 'survives' physics. Chapter 4 will contain various examples on the theories of relativity, but see also Esfeld (2015) on quantum mechanics and Monton (2006) on quantum gravity.

[9]Such thinking is rare in the literature, but for a recent example see Smolin and Verde (2021).

[10]By 'independently' I do not mean to imply, of course, that people and cultural groups are incapable of exerting *any* influence over the entities in their vicinity. For an introduction to this subject, and for more on what is meant by this 'independence', see A. Miller (2019).

[11]There are, it should be noted, some issues with conceiving of the field and the views within it in this way. For example, is our goal to describe the temporal structure as it *is* (simpliciter), or as it is, was, or will be (in a tensed sense)? See Deng (2018).

In this introductory chapter I will outline some of the key areas of debate concerning presentism. In §1.1 I introduce the view in more depth, contrast it to other views in the literature, and summarise its main challenges. I will then outline in §1.2 the objections that I will be addressing, and what the course of my arguments will be, throughout the rest of the thesis. Of course, I will not be able to address *every* issue facing presentism. I will therefore conclude this chapter in §1.3 by briefly discussing what I regard as two of the most important problems facing presentism that will *not* be addressed in detail later on: those concerning temporal passage, and scientific anti-realism. I will introduce these problems, and provide some indication of my views on them, before explaining why I have opted to set them aside in favour of addressing other challenges.

1.1. A first look at presentism

I will begin by introducing some of the more popular temporal ontologies in the literature, in §1.1.1. I will then summarise the strengths and weaknesses of presentism specifically in §1.1.2, before discussing the declining popularity of presentism in §1.1.3. Identifying these issues will allow for me to outline, in §1.2, how I will be defending presentism throughout the rest of the thesis.

1.1.1 Theories of time in the literature

There are several ways in which theories of time can be characterised. One traditional approach is to define a temporal *A-series* that sorts events into past, present, and future, and a temporal *B-series* that sorts events based on their earlier-than or later-than relations.[12] So a given event, like the inaugural Rugby World Cup Final, can be characterised in both an A-theoretic way (it is past) and

[12] For these terms we can thank McTaggart (1908), who defines the two series in order to criticise them both, and so argue that time is unreal. Pity that such an exciting argument should leave us with such unexciting terminology. For more on this view see N. Smith (2011).

a B-theoretic way (it is located on June 20th, 1987). Temporal ontologies can then be categorised into A-theories or B-theories, depending on which of these series they take to be *fundamental*.[13] A-theories are often called *dynamic*, because they generally invoke some notion of robust temporal passage, whereby that which is fundamentally present changes as time passes by.[14] While I will use these terms throughout the thesis where appropriate, there will be moments where the A-/B-theoretic distinction is suboptimal. For example in chapter 2 I will argue that presentists, who are traditionally thought of as A-theorists, might not take A-properties like *presentness* to be fundamental after all. In this section it will make sense to approach theories from a different angle: namely, to focus on what *exists*, in the most unrestricted sense of the word.[15]

Presentism is the theory that only present things exist.[16] You, the reader, exist, as do the words you are reading, and the cup of tea in your hand.[17] Past things like dinosaurs, Aristotle, and the 1987 Rugby World Cup Final do not exist: they are wholeheartedly *gone*. Future things like quantum computers, Martian colonies, and Marxist utopias do not exist yet. Some might think that the present has temporal *thickness*, so that a duration of (say) one microsecond of reality exists, but nothing before or after.[18] In this thesis, however, I will defend a conception of presentism wherein the present has no thickness in time. Instead, reality has only three spatial dimensions,[19] with no fourth temporal

[13]Some have questioned whether there is a meaningful distinction between A- and B-theories. See C. Williams (1996) and Oaklander (2012).

[14]I will return to this issue in §1.3.1, but see also Prior (1962) and Skow (2015, ch. 3).

[15]This is also a traditional approach, formal statements of which tend to lean on unrestricted *quantifiers*. See Crisp (2003) and Sider (2006) for details, particularly in relation to presentism.

[16]For overviews see Magalhães and Oaklander (2010) and Ingram and Tallant (2018). Notable proponents of presentism include Arthur Prior (1968) and John Bigelow (1996).

[17]If the reader does not have a cup of tea in their hand, I recommend that they seek one out.

[18]See for example Hestevold (2008) and Baron (2012).

[19]Barring any surprises from (say) string theorists, who generally argue for more than three spatial dimensions. Of course, string theorists also posit temporal dimension(s), and might reject a firm distinction between the two. For an introduction see Zwiebach (2009, pp. 7-9).

dimension in which any thickness could exist. The presentist accepts that reality *changes*, so she might also accept that representative tools like a temporal axis or 'timeline' are useful when modelling that change. She denies, however, that change necessitates the existence of a real, physical temporal dimension.

Perhaps the most popular rival view to presentism is eternalism.[20] This is the theory that past, present, and future things all exist in a four-dimensional 'block-universe'. Aristotle is real and physical, just as you are. He is not situated at your temporal location, just as he might not be at your spatial location, but he and everything else are still *out there* at the various spatiotemporal locations that they have. Under this view, a temporal dimension is not just a useful way to *model* change, but rather it is an existing feature of the external world. The eternalist believes that there is nothing special about a particular 'present' time. People refer to the time in which they happen to be located as 'the present', but there is no further notion of an *absolute* or subject-independent present, nor any notion of such a present undergoing robust temporal *passage*.[21] Instead, eternalists tend to define change in a purely 'at-at' sense: to say that something changes is just to say that it exists at one time, with one set of features, and also at another time, with a different set of features.[22]

There are many other temporal ontologies, which often mix together various commitments of both presentism and eternalism. Two are worth mentioning here. Firstly, under the moving spotlight theory past, present, and future things exist á la eternalism, but within the four-dimensional world there is a specific three-dimensional *slice* that is absolutely present. The passage of time consists of the present slice ceasing to be present, as the next slice becomes so. As Broad

[20]Notable proponents of eternalism, or similar views, include Bertrand Russell (1937, ch. 54), W. V. Quine (1960, ch. 5), David Lewis (1976/86), and Robin Le Poidevin (1991).

[21]There have been attempts to incorporate temporal passage, in some other form, into an eternalist world. See for example Savitt (2002), Deng (2013), Ismael (2016), and Leininger (2021).

[22]See Russell (1937, pp. 465-473) for a detailed examination of such change.

puts it, 'we imagine the characteristic of presentness as moving, somewhat like the spot of light from a policeman's bull's-eye traversing the fronts of the houses in a street' (1923, p. 59). Though this view is discussed at length in the literature, it has failed to attract much in the way of serious supporters.[23] Even Broad himself, to whom the theory owes its name, rejected it in favour of a different ontology: the growing block theory.[24] This is a second important example that incorporates elements of both presentism and eternalism. As Broad puts it, the growing block theorist 'accepts the reality of the present and the past, but holds that the future is simply nothing at all' (1923, p. 66).[25] Dinosaurs and the 1987 Rugby World Cup Final exist, whereas Martian colonies and Marxist utopias do not. This four-dimensional universe *grows* as time passes, as newly-formed events and entities accrete onto the growing edge of the block, and it is this growing edge itself that is identified as the absolute present.[26]

While there are other ontologies that could be listed here,[27] this thesis will mostly focus on presentism. One exception is in chapter 4, where my arguments can be adapted to any A-theory, including presentism, the growing block, and the moving spotlight. Elsewhere I will only occasionally reference the other ontologies above, as the main alternatives to the presentist position.

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[23]Deasy remarks 'the moving spotlight does not deserve its current relative unpopularity' (2015, p. 2073), and Skow admits to having 'a tremendous amount of sympathy' (2015, p. 3) for the view. Yet neither personally endorse it. See also Deasy (2018b) for a response to Skow.

[24]Though he was never a moving spotlight theorist, Broad's views did shift considerably across his lifetime. See Thomas (2019) for details.

[25]Modern proponents of the growing block theory include Tooley (1997) and Ellis (2014).

[26]Since both the moving spotlight and growing block admit an absolute present, and also other times, they face an epistemic problem. How could we know if we exist in the present or not? See Bourne (2002), Braddon-Mitchell (2004), Forrest (2004), and Heathwood (2005).

[27]See for example Belnap (1992), Sharlow (2007), and McCall (2009) on branching spacetime theories, and Norton (2014) for speculation about the *shrinking* block theory.

1.1.2 Strengths and weaknesses of presentism

Advocates of presentism point to three possible advantages of their position. Whether presentism in fact has these advantages is a point of dispute, and even if it does, these advantages might be shared by at least some other temporal ontologies. I will not enter into these debates below. Instead, I will merely take note of what the purported advantages of presentism are supposed to be.

Firstly, presentism might be more *intuitive* than its rivals.[28] Pre-theoretically, Aristotle does not seem to 'still live' in any sense other than in the records and traces of his life that linger in culture and memory. Fossils exist, but living breathing dinosaurs do not: it is intuitive to say of them that, rather than being *out there*, they are simply no more. Such an attitude seems to be reflected in the language that we use to describe the past.[29] We talk of past things as being *gone*, and we thank goodness that they are *over*.[30] While recent experimental work has called the intuitiveness of presentism into question,[31] even opponents of presentism still occasionally concede its intuitive strength.[32]

Secondly, presentism might be more *parsimonious* than its rivals.[33] If it can account for our observations as well as other views, for example, then Occam's razor might favour the presentist position.[34] Why believe in a fourth temporal dimension, if the three spatial dimensions alone would do? Expanding our ontology to include dinosaurs despite having no direct means to observe that

[28] See Bigelow (1996) and Tallant (2009, p. 425).

[29] I cannot comment on how far this extends beyond English, but Bigelow has claimed that presentism 'is written into the grammar of every natural language' (1996, p. 35).

[30] To paraphrase the famous line from Prior (1959).

[31] See Latham, K. Miller, and Norton (2020; 2021; forthcoming).

[32] See for example Sider (2001, p. 11).

[33] Bourne (2006a, pp. 68-69) and Tallant (2013) defend presentism's *quantitative* parsimony. My arguments in chapter 2 could also contribute to presentism's *qualitative* parsimony.

[34] For more on parsimony and its definition see Quine (1963), Sober (2006), and Baker (2016).

they are *there* would at least require serious justification.[35] If such an ontology turns out to be necessary in order to explain our best physics, say, then believing in eternalism might be reasonable. If it does not, then one might argue that the simpler ontology of presentism is preferable 'by default'.

Thirdly, presentism might be compatible with other attractive notions that are incompatible with some rival views. Consider for example the theory that the future is *open*: things yet to come are in some sense unfixed or unsettled.[36] This seems to align with the theory that the future is unreal: after all, future things could hardly be fixed or settled if they do not exist. Within other views, openness might be harder to accommodate. Eternalists might deny that what exists at one time *determines* what follows,[37] but they do seem committed to there being future things, in particular states, even when considered *from the standpoint* of here and now. So it seems that, within eternalism, there is at least some sense in which the future is *fixed*. Similar debates exist over eternalism's consistency with free will.[38] Eternalists may of course be able to defend themselves, either by denying openness or free will, or by arguing that their view is compatible with them.[39] It is a plausible attraction of presentism, however, that it might more easily accommodate for intuitive notions of this kind.[40]

So there are at least some attractions of presentism. What of its costs? There are four main objections that are worth noting here. Firstly, some have argued that presentism is ill-defined as a metaphysical thesis. If both presentists and

[35]Bigelow recognises the seriousness of this 'ontological expenditure' (1996, p. 47), but he concedes that presentism expends the same elsewhere. I will return to this issue in chapter 3.

[36]For details on openness see Barnes and Cameron (2008) and Grandjean (2021).

[37]For more on determinism, and the distinctions between it and notions like openness or chance, see Earman (2006, ch. 2), Myrvold (2012), Hoefer (2016), and Müller and Placek (2016).

[38]See Campbell (2011, pp. 7-12) and Gisin (2017).

[39]See for example Lewis (1979).

[40]Łukasiewicz (1930/1967; 1961/1967), for example, supported a view where indeterminism, three-valued logic, and the unreality of the nonpresent are mutually reinforcing ideas.

their rivals agree that the past existed, the present exists now, and the future will exist later, then what are they disagreeing about? Whether nonpresent things exist *simpliciter* might not be a clearly-defined point of contention.[41] There are also concerns over whether the boundaries of presentism are well-set. Which views count as presentist, and which do not?[42] The initial definition I gave earlier, 'only the present exists', turns out to be in some ways problematic, but attempts to define presentism more precisely have struggled to account for the diversity of theories that have been called presentist in the literature. So the first challenge is to properly outline what presentism even is.

Secondly, some have argued that temporal *passage* is a problematic or ill-defined notion within A-theories such as presentism.[43] The presentist accepts that reality changes, but she denies that this requires entities to be distributed across a temporal dimension. Critics argue, however, that a temporal dimension constitutes the best, and perhaps the *only* way to understand change.[44] The presentist will need to clearly establish an alternative account of change, but it is unclear whether this can be accomplished.

Thirdly, presentists face some problems with *truthmaking*.[45] Most presentists concede that, while there is no past, there is still a set of absolute, objective *truths* about the past. It is then unclear what it is that *makes* those truths true, when no past exists to ground them.[46] This problem becomes particularly concerning in cases where no presently-existing records or traces could pick out some claims from others. For example, one day a specific dinosaur (let's call her Dorothy) has vine leaves for breakfast. 10 million years later there remain no fossils,

[41] See C. Williams (1996), Meyer (2005), Savitt (2006), Deng (2018), and Deasy (2019b).

[42] See Deasy (2017) and Tallant and Ingram (2021).

[43] See D. Williams (1951), Grünbaum (1967), Prosser (2007), and Leininger (2015).

[44] I direct the reader again to Russell (1937, pp. 469-473) for a classic defence of this point.

[45] See Keller (2004), Caplan and Sanson (2011), Baia (2012), and Torrengo (2013).

[46] For introductions to this notion of truthmaking see Fine (2017) and Cameron (2018).

prints, or evidence that might be used to extrapolate that information. So what makes it true, today, that Dorothy once had vine leaves for breakfast? In rival ontologies the past exists, and so Dorothy exists *out there* eating vine leaves, which can ground this truth. Presentists have no such solution, and so might be worse-equipped to account for truthmaking than their rivals.

Finally, presentism is accused of contradicting our best physics. The theories of relativity in particular paint a picture of the world that is four-dimensional, where entities are distributed in curved *spacetime*, and where observers can run into irresolvable disagreements about which events were simultaneous with which. Such a picture does not seem to admit an absolute present,[47] and may also exclude temporal passage or flow.[48] If presentism is plainly disproved by physics, then that would be damning for the theory. Even if presentists can avoid contradicting physics outright, one might still argue that the theories of relativity *favour* other, four-dimensional ontologies like eternalism.

1.1.3 Presentism in decline

It is worth reviewing the state of play among philosophers of time, given the debates above. Are there many presentists out there, or are the drawbacks too serious to be bourne? While I will not be examining the history in detail, the story of presentism in recent centuries seems to be one of decline. Presentism has deep historical roots: in the 4th century St. Augustine claimed that 'there are neither times future nor times past' (1955, p. 436). He believed that the past and future exist only as representations in the present, and that 'the present has no extension whatever' (1955, pp. 433-434). Shcherbatsky also describes presentist thought within Indian Buddhism from at least as early as the 7th century:

[47] See Putnam (1967), Savitt (2000), and Wüthrich (2013).

[48] For discussions on this point see Gödel (1949) and Dieks (1988).

'everything past is unreal, everything future is unreal... Ultimately, real is only the present moment' (1962, p. 70). Bigelow even claims that presentism 'was believed by everyone, both the philosophers and the folk, until at least the nineteenth century' (1996, p. 35). This is likely too bold: there are many historical ontologies that do not seem to be presentist.[49] In the West, there is debate over whether St Anselm was an eternalist.[50] As for the Buddhists, Warder (1980, pp. 141-150) describes no less than 62 temporal theories, supposedly held by various groups, which were rejected by the Buddha. The Sarvāstivāda school would go on to maintain the existence of *dharmas* in 'the three times' (past, present, and future), while the Vibhajyavāda school put them in only the past and present.[51] So while presentism has an impressive history, there is also a history of competing views resembling the rival ontologies above.

Among the modern philosophical community, presentism has not proven to be popular. The advent of relativistic physics in the 19th and 20th centuries led to new challenges for presentism. Bigelow also interprets the emergence of time travel stories during this period as evidence of rival views 'brewing in the Zeitgeist' (1996, p. 35).[52] A survey of philosophers by Bourget and Chalmers (2014) found that only 15.5% of 931 faculty members supported or leaned towards the A-theories. B-theories were more popular (26.3%), though the largest group (58.2%) were unfamiliar, agnostic, or held 'other' views. In a follow-up study (2021), 17.1% of 1785 respondents supported or leaned towards the A-theories. In a more focused question (excluding those who skipped or indicated their

[49] One might think of Parmenides, who denied the reality of change. See Copleston (1953, p. 50) and Lombard (2010). In chapter 2 I will argue that a changeless *three-dimensional* world could be considered presentist, but it is unclear if this the view Parmenides took.

[50] See Rogers (2007) for this view and Leftow (2009) for a response.

[51] Warder (1980, pp. 272-275) describes the historical schism around this 'eternalism'. See also Shcherbatsky (1962, pp. 79-80) and Vasubandhu and de la Vallée Poussin (1990, pp. 805-808).

[52] It is remarkable that, despite no shortage of belief in gods, demons, and magics, time travel stories seem to be almost unheard-of *anywhere* until the 19th century, in works such as H. G. Wells' *The Time Traveller* (1895). For more on the history of time travel stories see Bailey (1947).

unfamiliarity with the subject), 18.4% of 736 respondents supported or leaned towards presentism, less than half of those who favoured eternalism (39.9%). So why have we turned away from presentism? One plausible explanation is that presentists might have failed to resolve the objections at their door.

Another issue worth identifying is that the adaptations made by presentists, when responding to their critics, can undermine the positive case for supporting their view in the first place. A common presentist strategy is to introduce new ontological machinery that, while perhaps answering the challenge(s) at hand, only does so by trading off on presentism's intuitiveness or parismony. When it comes to truthmaking, for example, Keller claims that 'the truthmaking problem does not refute presentism, but it does leave the presentist with the [burden of] showing that it is worth making the unattractive commitments that such an account will inevitably involve' (2004, p. 102). Caplan and Sanson remark that 'the attempt to save presentism and truthmaking... has led to a rich landscape of metaphysical views and mysterious posits. But these views continue to disappoint: if they don't founder on the rocks of hypotheticality, they miss the boat when it comes to explanation' (2011, p. 203). Meanwhile, when it comes to relativity, Wüthrich remarks that 'the tension between modern physics and presentism can be resolved, but... all resolutions either require unpalatable metaphysics or speculative science, which our best current knowledge cannot support. On the first option, the presentist position may become so disfigured as to more than offset any advantage that may have been gained' (2013, p. 21). This problem will be a recurring theme throughout the thesis. In chapters 2, 3, and 4 I will provide a more detailed examination of the defences presentists have offered, and the problems that they have led to. A core goal of this thesis will be to do better: to defend presentism against its objections, while retaining the simple, 'stripped down' ontology that presentists wish to boast.

1.2. Aims of the thesis

My primary goal in this thesis is to defend presentism from its critics. Most of my arguments will therefore focus on the various challenges that were listed in §1.1.2. While I will not provide a general analysis of presentism's *advantages*, I will argue that the defences I provide have several specific merits over those that have been attempted before. A unifying theme will be that my defences avoid radical or needless expansions of the presentist's ontology or alethiology. I aim to keep presentism *limited*, and although the benefits of this will differ depending on the defence in question, I anticipate that my arguments should all in part help to keep presentism *parsimonious*, however that notion might be understood. Some of the arguments I raise may also contribute to presentism's *intuitiveness*, but this will be a lesser priority.[53]

In chapter 2 I address the objection that presentism is ill-defined. I highlight several problems facing the definitions of presentism in the literature, including some issues identified elsewhere, and some others that are new. I then defend a definition of presentism that avoids these problems. I propose that presentism should be understood as a negative thesis about time rather than a positive one. The core of presentism is not a particular understanding of how time *is*, but rather an understanding of how time *isn't*: namely, time does not constitute a topological dimension, and accordingly there is no such thing as temporal extension. I call this view *topological three-dimensionalism*, and defend it as a precise, formal definition of presentism. I therefore maintain that presentists can overcome the objection that their view is ill-defined.

[53] Given the emphasis placed on the intuitiveness of presentism elsewhere, the reader might wonder why I deprioritise it. Perhaps it stems from my background in the sciences, where arguments invoking folk intuition are treated with a distrusting eye. While I find presentism intuitive myself, I would hestitate to claim from my armchair that a single view is intuitive for everyone across all cultures, though I break this rule somewhat in §1.3.1. Regardless, I am not inclined to regard intuitiveness as an important strength for this, or any, temporal ontology.

In chapter 3 I discuss presentist truthmaking. It has generally been assumed that presentists must believe in a set of truths about the past, despite the past not existing. It is in the process of defending such a position that presentists often introduce problematic complications into an otherwise simple ontology. In this chapter I argue that presentists would do better by denying that there are any truths about the past or future. What we have in the present, including records, fossils, memories, and the like, are sufficient to account for what we experience and observe in the world. There is no need for a further underlying set of past *truths*. Many may find this move unintuitive: in that case, this argument can be thought of as trading out on the intuitiveness of presentism in order to preserve its other attractions. Regardless, I maintain that presentists can overcome the objection that there are truths about the past that their view cannot account for, at least without further *complicating* their ontology.

In chapter 4 I examine the argument from relativity. My defence covers not only presentism, but also the broader school of A-theories to which presentism belongs. I argue that this objection has been posed elsewhere in a problematic way: critics assume that A-theories, including presentism, can be treated as views where the present is *located within* four-dimensional spacetime. While I agree that A-theorists should accept relativistic spacetime as a useful model for doing physics, I argue that the objection from relativity should be construed from the beginning as a problem of matching ontological claims to claims about relativistic *observations*. I then argue that our lack of observations of absolute simultaneity does not preclude there existing an absolute *present*, so long as we clearly understand what constitutes an absolute present, and what constitutes simultaneity or *copresentness*. I therefore maintain that A-theorists can reconcile their views with the theories of relativity, without resorting to denials of the physics, or to extensive ontological modifications.

Chapter 4 marks a shift of focus towards the interplay between presentism and physics. This continues into chapter 5, where I will also move from merely defending presentism against objections to instead proposing a novel *advantage* of the view. I argue that adopting presentism allows for quantum theory to be interpreted in new and interesting ways. In particular, presentism allows for both an open future, and even an open *past*, which gives the presentist unique tools for explaining the strange and probablistic behaviour of quantum systems. My goal in this chapter will be modest: I will merely aim to show that there is promise in this line of thinking, and that presentist approaches to quantum theory would be worth exploring further.

Once my four main arguments are made, I will conclude in chapter 6 by bringing them together into a single coherent picture of presentism. I defend an ontology where reality is three-dimensional, with no temporal extension; where there are only truths about the existing present; where the results of relativistic observations are accounted for; and where some of the behaviours of quantum systems are interpreted to be consequences of presentist ontology. Of course, I will not address *every* problem facing presentism in this thesis, and so there will remain some questions to be asked of the view that I conclude with. In particular there are two issues that, while not the focus of any of the chapters, will arise at several points as peripheral or secondary concerns. These are, firstly, the problem of temporal *passage* introduced in §1.1.2, and secondly, the extent to which presentists must commit to scientific *anti-realism*. I do not neglect these issues because I believe them to be unimportant: on the contrary, I think it is crucial for presentists to have a clear account of passage, and a clear account of how to interpret our best science. Given that, in the next section I will briefly express my own views on each of these problems, while also explaining why I have largely left these issues aside throughout the rest of the thesis.

1.3. Two initial problems for presentism

Physicists often model systems in terms of a given initial state, coupled with a set of equations governing the system's evolution. The job of the physicist is to use those equations to calculate one or more possible pasts or futures, into or out of which the initial state could evolve. Intuitively, we might be *realists* about at least the initial state. The state is supposed to be a straightforward, though simplified, representation of something that exists. In chapter 2 I will elaborate on the presentist's belief that reality is *three-dimensional*. For now it is enough to note that presentists would represent physical systems with a merely three-dimensional state, coupled with a set of evolution equations. This, to my mind, captures the presentist ontology in a nutshell: reality is three-dimensional, and yet *changing* in some kind of systematic way.

This picture of presentism raises two initial problems. Firstly, what does 'changing' mean in this context? This amounts to the familiar temporal passage problem flagged in §1.1.2. Secondly, if one is a realist about the initial state, should one also be a realist about the evolution equations, or about the other states that are extrapolated from the initial state plus the equations? At the very least, it seems like presentists cannot be realists about entire distributions of states across time, but the significance of this as a form of scientific *anti-realism* has not seen much discussion in the literature. These issues will reappear at several points in the thesis, but I will not seek at any stage to comprehensively defend a particular stance on either of them. My aim in this section is simply to introduce each issue, indicate my views regarding them, and then elaborate on my reasons for sidelining them in favour of other problems.

1.3.1 Presentism and temporal passage

As I will elaborate on in chapter 2, the presentist believes that reality is three-dimensional and *changing*. Whatever 'change' is, it is not understood to imply that there exists a fourth dimension. The sceptic might challenge the presentist to explain this notion of change, or *passage*.[54] A similar challenge can be posed for any temporal A-theory, and as such there is a rich literature concerning this problem.[55] There has also been a great deal said about passage in the context of physics.[56] So I can understand if the reader feels that it would be suitable to address this topic in detail in a thesis of this kind.

In my view the question being asked of presentists can be divided in two. Firstly, the critic might claim to lack even a basic, first-pass understanding of what presentist temporal passage could be. She might have no comprehension of what the presentist is 'getting at' when they talk of three-dimensional reality changing, without such talk obviously and intuitively invoking a fourth, temporal dimension. Secondly, some critics might admit to a basic understanding of what this talk of passage is 'getting at', but they might challenge presentists to provide a more detailed breakdown of this notion. In terms of what else, more fundamental than passage, might passage itself be understood?

When it comes to the first question, I believe that there is a clear response to those who deny even a basic or intuitive understanding of what passage within presentism might be. Take, for example, your intuitions regarding your sense of *sight*.[57] We seem to see things around us as three-dimensional. We can point to

[54]Here, I seem to conflate change with passage. Under the view proposed in chapter 3, change only exists in sense that reality undergoes passage, so one can talk of these interchangeably. Other presentists, however, might define change in terms of *truths* about various times.

[55]See Savitt (2002), Dainton (2011), Skow (2015), Ismael (2017), and Deasy (2018a).

[56]See Grünbaum (1967), Hartle (2005), Norton (2010), Ismael (2016), and Arthur (2019).

[57]I merely refer to how what you see appears to you, at first pass. As for the technical details of eyes and optic nerves, there is also reason to think that perceptions of change are irreducible to 'static' information about entities at a series of times. See Shaw and Pittenger (1978).

up to three visibly orthogonal directions: not two, not four. And yet, we seem to see things changing. The fact that we see things changing does not *prima facie* make us *see* them as four-dimensional, even if a fourth dimension were something that we might *reason* to exist, beyond what we merely see. So we already find one arena - sight - where change manifests in a way that does not, at first pass, involve extension along a fourth temporal dimension.[58] Although I have scruples about assuming anything to be *universally* intuitive, in this case I will be so bold: I am yet to meet anyone who claims to straightfowardly and intuitively see things in four dimensions, nor anyone who claims to straightfowardly and intuitively see things as unchanging.

Given this, I will assume that the reader has a basic understanding of what temporal passage looks like in a presentist world. To say that reality is three-dimensional and changing is to say that reality is, *very* broadly speaking, how it looks like it is. This explication is so broad that it is more of a description of a phenomenon than a definition of passage: I am yet to put into words exactly what passage is. This brings us to the second question: how can the presentist define passage *precisely*, without invoking a fourth dimension? Two strategies are possible. Firstly, the presentist might define passage outright, in a precise and detailed way. Alternatively, she might reject that passage can, or needs to be, defined in any more precision than the intuitive picture already introduced. Passage might, for example, be *primitive* or *fundamental*, in such a way that it cannot be precisely defined in terms of other concepts.[59] This need not be a problem, so long as a more detailed definition of passage is not required in order for the presentist to address the other challenges facing her.

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[58] I will not analyse here whether we perceive or experience a more rich notion of temporal passage. There are many who claim that we do not: see Prosser (2012), Hoerl (2014), K. Miller, Holcombe, and Latham (2018), and K. Miller (2019a).

[59] For an example of a primitivist view, albeit not within presentism, see Maudlin (2007, ch. 4).

So why do I not address passage in more detail in this thesis? Firstly, even if presentism is true and passage exists, the task of defining it might be very difficult or even impossible. I do not wish to *commit* to the stance that passage is primitive, but I think it is a distinct possibility. Even if there is hope of finding a precise definition, I am not confident that A-theorists are close to it yet. My brushes with Buddhist thought suggest a history there of both presentist thinking, and an interest in change, and so I suspect that the history and philosophy of Buddhism might be fertile ground for this subject.[60] Here we reach an area that is not my field of expertise, and where collaborations beyond the scope of this thesis might be in order.

I also take seriously the possibility that passage might not *need* to be defined precisely, in order to support presentism. Of course, more clarity on this topic would never be a *bad* thing, but I am hopeful that a first-pass understanding of passage might be sufficient for the arguments that I raise. While there are some interesting questions to be asked about passage, I do not find myself harbouring a deep-seated desire to understand what it means for three-dimensional things to change, beyond the basic notion that seems obvious to the senses. If further details are not necessary for one to get on with the business of defending presentism, then I am inclined to leave this issue aside, though I will note at various points in the thesis when questions about passage become relevant.

1.3.2 Presentism and scientific anti-realism

Next, I will consider whether presentists might be committed to some form of scientific anti-realism. As in the case of temporal passage, I address this subject now because it will become relevant again at several points in the thesis. It will pay to initially clarify what my assumptions about anti-realism will be, and

[60] For example Shcherbatsky (1962, pp. 79–86) describes as prevalent a historical view where reality is both *instantaneous* and essentially *kinetic*.

also why I refrain from raising any more detailed arguments about it. Earlier I indicated two things that presentists might be anti-realists about: the various states across time that scientists describe when modelling physical systems, and the evolution equations (or *laws*). I will examine each of these in turn, providing an indication of the kind of anti-realism that presentists might adopt.

Firstly, consider the distributions of states across time that are invoked in our best science. Physicists often describe systems at various states throughout an entire course of evolution, or *trajectory*, without making any references to which point in that trajectory (if any) is the present. Earlier I characterised these states as the results of extrapolations from just one *initial* state, but it is not always obvious which state (if any) holds the privileged position of being that initial state. Instead, systems are modelled by indifferent distributions of states acoss four-dimensional *spacetime*. If presentists are to maintain that only the present exists, then they must reject that these spacetime models are straightforward depictions of reality.[61] In this sense, at least, all presentists must be anti-realists about spacetime models. Of course, many presentists maintain belief in a set of absolute *truths* about the past, present, and future, and they might understand spacetime models to straightforwardly depict those truths. In chapter 3 I reject this position, however, arguing that presentists should abandon the notion that there are truths about the unreal past and future. This commits me to a stronger version of anti-realism about spacetime models: they are at most useful tools for experimentation, and a reflection of the evidence and records that exist *presently*, but there are no existing nonpresent things, nor any underlying truths about nonpresent things, to which our spacetime models correspond.

How might one defend an anti-realist position of this kind? One option would be to defend scientific anti-realism more broadly. Perhaps a great deal of

[61] In chapter 4 I note that growing block and moving spotlight theorists must also take spacetime models to be 'missing something' about reality: its growing edge, or its spotlight, respectively.

scientific discourse should be understood as merely useful, without assuming that it maps onto anything out in the world.[62] If that were so, then by *default* we would be instrumentalists about spacetime manifolds, unless there was some compelling reason to believe otherwise. While this is one option available to the presentist, it is not my own preference: in general I would consider myself to be a scientific realist.[63] However, I believe that at least two independent defences can be given for anti-realism about spacetime manifolds, and the distribution of states represented in them, even if one is a realist about science more broadly.

Firstly, spacetime manifolds might not seem to contain an 'initial' state, from which all other states are derived, when they are used in theoretical problems. However, this state *can* be identified when dealing with experiments in practice. In theoretical problems we limit our scope to a series of times t_0 through t_n over which some process is represented to occur. At most we might pick one time (often t_0) to be called the 'initial' state, but this does not give any obvious leeway for distinguishing a real present state from unreal nonpresent states. In practice, however, we must also consider the state of the experimenter themselves, as they reflect on the experiment after its conclusion. It is this state that we can think of as the 'initial' one: the experimenter uses information in their vicinity such as numbers written in their ledger, alongside a working theory about the laws of nature, to represent a series of states in the past. In chapter 4 I discuss further this 'backward-looking' feature of observation. For now, it is enough to note that when spacetime models are deployed in practice, they *are* used to extrapolate representations of many states from just one 'initial' state. So we can plausibly regard that one (present) state as real, but treat the greater series merely as a useful representation or tool.

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[62]For an overview and defence of anti-realism see van Fraassen (1980, ch. 2).

[63]For more on the realist position see Hacking (1982) and Chakravartty (2017).

Secondly, I would argue that instrumentalism about distributions of states in physics aligns well with our talk of similar distributions in everyday contexts. In §1.1.2 I noted that presentists take their view to be *intuitive*, but this is not to deny that we often talk about indifferent distributions of events across time. Writers of encyclopedia entries or train timetables, for example, merely note the order in which events do or should occur, perhaps with *times* attached, but without indicating what time it is *now*. This is purposeful: documents of this kind provide ongoing guidance, omitting any information that would quickly become misleading as the present changes. It would be odd to regard anyone using a train timetable as committed to the existence of the past or future, just because they find it useful to represent events across time indifferently in that particular context. It is plausible that physicists would also omit information about the present in their models of physical systems, for the very same reason: they aim to provide useful ongoing guidance about systems of that kind. So I would argue that presentists can justify the same instrumentalism for spacetime manifolds as for train timetables. Of course, I am yet to consider whether specific *features* of these manifolds, such as their treatment of simultaneity, could create other problems for presentists. This will be the focus of chapter 4.

Even if presentists can justify anti-realism about distributions of *states* in the sciences, it remains the case that even the fundamental scientific *laws* tend to be written in ways that reference a variable of time, 't'. In chapter 5 I discuss applications of presentism to quantum theory, and the core evolution equation in that field is the Schrödinger equation, $i\hbar\frac{d}{dt}\left|\Psi(t)\right\rangle = \hat{H}\left|\Psi(t)\right\rangle$. If my arguments in chapters 2 and 3 stand, then presentists should avoid understanding reality in terms of *times*, and should also reject that there are *truths* about events across time. Does this imply that presentists should be anti-realists about laws? Are we to believe that the Schrödinger equation is *false*?

Here it will be worth distinguishing between two uses of 'scientific law'. On the one hand, there are laws as we write them down: specific equations using specific variables that play a role in our best theories, such as the Schrödinger equation. On the other hand, there are the *underlying* laws: some structure or order to the universe that we might think exists, and which constrains how reality is capable of evolving.[64] Of course, the two are linked: the equations are supposed to be representations of the underlying structure. It is specifically in the former case, however, that we find explicit use of the variable 't', and I would argue that anti-realism about these *equations* is a fairly straightforward position to defend. There are often many equivalent ways of mathematically representing the same constraints on the same system, and even if we could pick out just one of these, it would be bold to assume that today's best equations will never be overthrown by other alternatives. It would be equally bold to think that the particular variables used in today's equations, including 't', could never be supplanted. Cartwright (1980) also argues that our current best equations do not even reflect our current best knowledge about how things evolve. The laws, as they are written, are useful for *explaining* what we observe, but do not strictly 'state the facts'. I will assume, then, that presentists can plausibly adopt an instrumentalist view about the evolution equations.

What about the *underlying* laws? There are several ways of understanding these laws that are incompatible with the ontology that I defend. For example, I cannot define a natural law to be a universal true regularity across all *times*.[65] It is worth noting here that the underlying laws are meant to provide constraints on how reality can *change*. So to say that there is some structure or order to the

[64]There are known anti-realist views about these notions, with justifications that are distinct from anything to do with presentism. See for example Cartwright (1980) and Giere (1999).

[65]Of course, there are many problems with regularity theory, so this option will not be sorely missed. For an overview see Armstrong (1983, ch. 1–2).

universe is, in this context, just to say that things only change in thus-and-such a way. In §1.3.1 I explored the unique understanding of change that presentists defend: namely, they defend some form of robust temporal *passage*. To say that reality only changes in thus-and-such a way is, under the view I defend, simply to say that passage exists in thus-and-such a form. So there is some structure to temporal passage: three-dimensional reality changes, but not in a way that is totally unstructured or chaotic. The evolution equations are, in turn, just our best representation of the constraints that exist on how things can change as a result of passage. For example, perhaps temporal passage exists in such a way that it does not 'touch' the overall electric charge of a system. We model this using equations that represent a system's charge as fixed across multiple *times*. The presentist is an instrumentalist about the equations: they deny that multiple times exist, and see such models merely as useful representations. However, the presentist could remain a realist about the 'underlying' laws, if they could maintain that passage exists in some sort of charge-conserving way.

This view of laws leaves presentists with some questions to answer. Firstly, how can passage exist in a particular *form*? For example, what *grounds* the fact that temporal passage leaves electric charge 'untouched', if there are no truths about nonpresent values of charge? Secondly, *why* is representing change in terms of times is so useful, if the times themselves are unreal? Why have we not discovered some other, superior physics that avoids references to times? None of these problems are specific to *laws*: rather, they bring us back to the general problem of passage discussed in §1.3.1. The presentist might not only have to define temporal passage generally, but also define the particular features of it, and what grounds those features. The presentist might also have to explain why, in practice, we find it useful to represent passage using times. These could be difficult questions to answer, but I see no obvious reason to think that they are unanswerable. For example, if presentists argued that temporal passage is *primitive* or *fundamental*, then they would not be surprised by the fact that even our most useful attempts at breaking down passage in mathematical detail end up misrepresenting it somehow. I will not attempt to offer any alternative, 'timeless' approaches to physics in this thesis. I suspect that doing so would be a significant task, involving a serious mathematical analysis that is outside of the scope of this project.[66] Instead, I simply accept in chapter 2 that it is often useful to model change in terms of states across time, and I use such representations myself when discussing presentist physics in chapter 5.

A proper discussion of anti-realism about laws would require more to be said on the subject of temporal passage, so I will not address this issue in any further detail here. Instead, I hope that the arguments raised in this thesis will be understandable simply by assuming a basic, first-pass notion of passage, and by assuming an instrumentalist view about the evolution equations, which are just useful representations of what passage is like. With these issues put to the side, there remain four big questions that this thesis will address more seriously. How should presentism be defined? How can presentists account for truths and truthmaking? How can presentists reconcile their theory with relativity? And how can presentists integrate their ontology with intepretations of quantum mechanics? These questions will be the focus of the four main chapters of this thesis, beginning with the question of presentism's definition.

[66]While some theories of quantum gravity are 'timeless', they draw on distributions of multiple, causally-related states. So they are generally not *presentist* theories. See Barbour (1994).

Chapter 2: Defining Presentism

Abstract

Presentism is traditionally defined as the theory that only present things exist. Several authors have recently challenged this definition, however, and have proposed alternatives of their own. In response Tallant and Ingram (2021) argue that none of these definitions will do, and instead there can be *no* precise definition of presentism. In this chapter I assess the competing definitions, and identify a new problem common to them. I argue that the best definition of presentism, if we were to adopt one, would be *negative*. Presentism should be understood as a theory about what time is *not*: that there is no temporal dimension, and no temporal extension. While I give reasons to adopt this view instead of abandoning presentism, I acknowledge that both options remain defensible.

2.1. Introduction

Elementary discussions of presentism often begin with a pair of broad ideas. Firstly, only the present exists, while the past and future are unreal. Secondly, reality is three-dimensional rather than four-dimensional. Of these ideas, the first seems at least in part to be a *positive* thesis. Everything that exists is thought to have some quality that makes it absolutely, objectively *present*, a quality that presentists believe in where their rivals may not. The second idea bears some positive content too, in so far as the presentist is claiming that there are three spatial dimensions. These dimensions would also generally be accepted by the presentist's rivals, however, so the *distinguishing* feature of this second claim is its negative content. Presentists deny that there is a temporal dimension, or that reality temporally extends.[1] So on the one hand, presentism can be understood as a positive thesis: reality contains and is limited to entities with particular features, like presentness, that are *not* found in other views. On the other hand, presentism can be understood as a negative thesis: reality does *not* contain particular features, like a temporal dimension, that *are* found in other views.

In this chapter I consider how presentism might be formally defined, beyond these elementary ideas. In the literature, something akin to the first, positive thesis is often taken to be the definition of presentism. The second, negative thesis is thought to be an *implication* of presentism, but not the definition of it. There is, however, a growing body of literature highlighting the problems that these typical definitions run into. In §2.2 I review these criticisms, and introduce some of my own. I argue that the positive commitments made in the process of defining presentism are at best unnecessary, and at worst unintelligible, within presentism itself. Presentism is being defined in terms of things that presentists should not, and perhaps *cannot*, believe in.

In §2.3 I introduce an alternative, *negative* definition. Presentism should be understood as a theory about what time is *not*: time is not a physical dimension akin to space; time is not a direction in which entities extend. Whatever form time or *change* takes, it is not of the sort that would invoke a fourth, temporal dimension. This approach avoids some of the problems facing positive definitions of presentism. There will remain, however, a serious challenge facing *all* definitions that has been identified by Tallant and Ingram (2021). They argue that there is no 'theoretical core' shared among the views that have been called presentist in the literature. Any definition will exclude some 'presentisms' from the presentist camp, a move that Tallant and Ingram deem unjustifiable. They conclude that there can be *no* good definition of presentism. In §2.4 I raise some

[1] Though some consider whether the present could be 'thick'. I discuss this further in §2.4.

problems with this argument, and defend my negative definition over no definition at all. With that said, my conclusion on this issue will be a modest one. While I have concerns about Tallant and Ingram's position, their argument remains defensible, and could yet succeed. The purpose of this chapter is not so much to argue that formally defining presentism is, itself, the right thing to do. Rather I will argue that, if we *assume* that a formal definition is something that we seek, then the best candidate on offer is a *negative* definition, which seems to have been overlooked thus far. Moving forward, the presentist should be weighing up between the pessimism of Tallant and Ingram, on the one hand, and the negativity of the approach that I defend, on the other.

2.2. Presentism in the literature

Presentism is often defined in as little as a sentence. Typically, this is one of several similar sentences about the existence or nonexistence of the present or nonpresent. Examples include 'only present things exist', 'nothing exists which is not present', 'all and only present entities exist', and 'reality is limited to the present'.[2] These basic definitions lack clarity on a few important details. Firstly, what is meant by 'reality' or 'exist(s)'? Critics have noted that if 'exists' means 'exists *now*', then the above claims are trivial, whereas if 'exists' means 'exists now, existed, or will exist', then these claims are nontrivial but obviously false.[3] I will assume for now that there is a third, *tenseless* way of understanding existence that can be sensibly employed here, though I will revisit this issue in §2.3. Secondly, what is meant by the term 'present'? In some of these definitions it is unclear whether it is *objects* that are present, or whether there is a substantive present *time* distinct from any objects contained within. I will initially assume

[2]See Markosian (2004, p. 1), Bigelow (1996, p. 35), Asay and Baron (2014, p. 1), and Caplan and Sanson (2011, p. 196) respectively.

[3]For such critiques see Meyer (2005) and Lombard (2010), and see Sider (2006) for a response.

that presentists are just discussing objects, since they may not want to commit to a substantivalist view of times. It remains unclear, however, what it would mean for an object to *be present*. Is presentness a property, for example? If it was, then presentism could be defined as the theory that only objects with the property of presentness tenselessly exist.

This notion of *presentness* has faced serious criticism.[4] One of the issues raised by Craig (1997, p. 36) is that things must *already* be present, and thus existent, before they can have any properties. Sosa (1979) also argues that presentness could not be instantiated in either a tensed or tenseless fashion, leaving it unclear how it could be instantiated at all. More recently, Deasy (2017) has objected to both property and non-property approaches to presentness, and so looks to define presentism without reference to either. I am inclined towards a similar line of thinking. Whether it refers to a property or not, the term 'present' is hard to make sense of within presentism. Presentness is only meaningful if it differentiates things at the present time from other things at other times, but the presentist may not believe in *times*, nor in anything nonpresent for present things to be contrasted with. If presentness exists, then the presentist believes that *everything* has it, rendering it redundant. There are no clear, meaningful differences between a three-dimensional world where everything has presentness, and that same world where everything just exists, without presentness.[5]

Given these issues, Zimmerman (1996), Craig (1997), and Tallant (2014a; 2019) suggest that presentists adopt a *deflationary* view of presentness, so that to be present means nothing more than to exist.[6] Some things exist, while others

[4]Moore rejected it, but admitted its intuitiveness. 'It seems to be the plain truth that: every event has, when it is present, a characteristic wh. it does not possess at any other time–a characteristic wh. is what we mean by saying that at that time & no other it is present' (1962, p. 97).

[5]A similar point can be made for *co*presentness: this will be crucial in chapter 4.

[6]This might be taken to mean that presentness is not a property, though as Tallant (2019, p. 423) discusses, it could still be an 'uninteresting' property reducible to mere existence.

do not, but there is no further notion of things being present, or not.[7] I sympathise with this *existence presentism*: I think that presentists should reject that there is a property of presentness, and define their theories simply in terms of which things exist. Note, however, that existence presentism does not constitute a *definition* of presentism. Claiming that the set of present things is by definition the set of existing things does not tell us *what it is* that does or does not exist, which is something that a theory like presentism is supposed to do. As Deasy (2017, p. 383) points out, adopting existence presentism makes 'only the present exists' trivially true, and therefore consistent with any theory of time. So while existence presentism is a good start, there needs to be a further *definition* that clarifies how the presentist's ontology differs from those of other views.

So far, I have discussed how definitions that invoke *presentness* implicitly commit to something that exceeds what presentists could be expected to believe in. Presentists believe that you, the reader, exist, whereas Aristotle does not, but it is unclear why presentists would believe that you bear some presentness property that might *further* distinguish you from Aristotle. I will now argue that several other attempts at defining presentism have run into similar problems: they implicitly invoke particular positive theses that are themselves problematic for the presentist to adopt. In fact, other definitions may suffer from a *worse* version of this problem, as they require the presentist not merely to think that *existing* things have presentness, but rather to think that nonpresent things have certain features or properties, *even though they don't exist*. I shall now consider several examples that run into such problems.

After acknowledging the problems with *presentness*, Deasy suggests that presentism should be defined as 'there is an absolute, objective present instant... & sometimes, something begins to exist and sometimes, something ceases to

[7]This seems to suit Prior's 'redundancy theory' of the present tense: 'the proposition that it is (now) the case that p is the very same proposition as the proposition that p' (1968, p. 101).

exist' (2017, p. 391).[8] This definition draws on terms like 'present instant' and 'sometimes', while the further particulars of this definition use language such as '(n)ever' and 'always'. In order to adopt this view, presentists would need to believe in several positive claims about instants, and about things being sometimes, always, or never thus-and-so. Correia and Rosenkranz (2015) also define presentism without invoking presentness, and to their credit they take significant precautions to define the temporal language that they use.[9] Yet one term (such as 'being in time') is often defined with respect to other, unexplained terms (such as 'sometimes' or 'times, t'). Whether it is the term 'present', or whether it is supposedly more fundamental or obvious terms like 'times', these definitions use language that at the least requires further explanation in order to be understandable.[10] The presentist must explain how it can positively be the case, within her theory, that there could be *times* or *instants*, or that entities could be *sometimes* thus-and-so. Are we to understand, for example, that the presentist believes that everything exists *at a time* - the present one - and there are, in some sense, other times that the present can be sensibly compared to?[11] Are we to understand 'sometimes' to mean 'at some of the *many* times'?

Outside of works that focus specifically on defining it, presentism is often construed in a more explicitly four-dimensionalist manner. In the literature on relativity and its implications for presentism, for example, presentism is often posed as the theory that there is a three-dimensional hypersurface of existing things, which somehow sits within the greater four-dimensional manifold of relativistic spacetime. One finds this approach among both presentists and their

[8]The latter claim is called *temporaryism*. Some argue that debates about presentism could be abandoned, in favour of debates about temporaryism against *permanentism*. See Deasy (2019a).

[9]For brevity I will not labour over the wording of Correia and Rosenkranz's view. They define presentism as 'always, $\exists t$(t is one-off&x(x is in time$\rightarrow$x is contemporaneous with t))' (2015, p 6), but to understand terms like 'one-off' I would direct the reader to the paper itself.

[10]For a number of other concerns regarding these two definitions, see Tallant (2019, pp. 410-421).

[11]See Hestevold (2008) for a critique of this approach to times.

critics,[12] who often assume such a view at the beginnings of their articles, without much explanation as to how it is to be understood. In defence of these thinkers, adding a 'slice' of existents to an otherwise four-dimensional picture does *intuitively* seem to capture presentism, while constituting a minimal departure from the models of our best physics. It is not obvious that such a picture of presentism could be accurate, however, when the whole point of presentism is to deny the existence of the rest of the manifold, making it difficult to maintain that the present 'sits within' a manifold in any sense at all.[13] I will examine the conflict between relativity and presentism in chapter 4. In general I suspect that the most promising approaches to this problem may revolve around the discrepancies between the four-dimensional 'presentism' that the critics attack, and *proper* presentism (whatever that looks like).

A recurring theme among these views is that they seem to implicitly commit the presentist to *times*, to *spacetime*, or to particular features of *nonpresent* things. The presentist must adopt one of two plausible methods for intepreting these notions. Firstly, she could take these terms to be a useful, but ultimately dispensable representation or metaphor for what she thinks. The presentist does not *believe in* multiple times, but she does talk of times in so far as doing so is useful. An initial criticism here is that if the presentist means something else by 'present' or 'times', then she would do better to define her theory directly in terms of whatever these words represent. I will adopt such a position in §2.3, where I argue that presentism should be defined in terms of topology, and terms like 'times' and 'present' might then be defined once a topological definition of presentism has been settled upon. It is not clear that other presentists are taking the same approach, however, when they use such language in their definitions.

[12]See Hinchliff (2000) and Monton (2006), and Putnam (1967) and Savitt (2000), respectively.

[13]This issue has been acknowledged elsewhere. See for example Prior (1972).

So I will first review what *else* these terms might represent, in order to show that the alternatives are not particularly promising. There is also a second approach to this problem: instead of understanding terms like 'times' to be metaphorical or representative, the presentist could take this talk more seriously. She might define her theory so that there can properly *be* times and instants within her ontology, and so in at least some sense, present things are genuinely located at the present time rather than at other times.

Consider the first approach. Presentism is defined as either 'only the present exists', or as some theory about what *times* there are and what happens at some of them, but the terms 'present' or 'times' represent something else. What do these terms represent? I will focus on the clearest option: most presentists maintain that, although the past does not exist, there does exist something else with sufficient representational content that it can ground *truths* about the past. Such entities are invoked by presentists in order to respond to the *truthmaker objection*: the claim that presentists cannot account for past-tensed truths.[14] I will discuss this problem in much more depth in chapter 3. For now, it will be sufficient to note that while presentists cannot draw upon past things to ground past truths, they might posit other things that do that grounding work instead. Some invoke special truthmaking *properties* for this purpose.[15] Others invoke abstract sets of propositions, called *ersatz times*, to fill that same role.[16] So-called *nefarious* presentists reject that anything existing grounds truths about the past, instead proposing that they are true in virtue of primitively tensed facts.[17] Each of these views could only succeed if these special properties, or ersatz times, or tensed facts had the right sort of representational content, such that they contained a

[14]For a summary see Caplan and Sanson (2011).

[15]For a variety of such properties see Bigelow (1996), Cameron (2011), and Ingram (2016).

[16]See Bourne (2006b) and Crisp (2007).

[17]This involves rejecting typical truthmaking principles, in favour of alternatives that incorporate tense. See Kierland and Monton (2007), Baia (2012), and Tallant and Ingram (2015).

good *record* of past events. This representational content might also allow for them to be the referrents of terms like ‘present’ and ‘times’. An *ersatz* presentist, for example, might define ‘only the present exists’ to mean ‘only things corresponding to one ersatz time exist’. Similarly, a term like ‘times’ could be taken to refer to ersatz times, rather than referring to times proper.

Alternatively, consider the second approach. Perhaps nonpresent times could have *some* ontological status within presentism, despite not *existing*. A variety of theories have been proposed where, in some sense, only the present exists, but in another sense, there is a past and future. One significant motivation for this approach is, again, that it might resolve the truthmaker objection. Crucially, if one grants the past and future some restricted ontological status, allowing for them to be truthmakers, then they should also have a sufficient ontological status to be the referrents of terms like ‘times’. I will summarise a few examples of such theories. Fiocco (2007) and Zimmerman (2011, pp. 197-201) both defend positions where present and nonpresent *times* exist, but only the present time is populated with objects. Nonpresent times are *empty*,[18] but they still bear the grounding relations necessary for truthmaking. Such a presentist could make sense of a term like ‘times’, since times literally exist; and of what it means to be *present*, at the only populated time. A second example are the Meinongian presentists, including Paolini Paoletti (2016), who argue that existence itself is a property that objects either have, or not. Nonexisting things lack one particular property, but they still have other properties, and bear relations, and do explanatory work. Markosian (2004) defends a similar position where nonpresent things are granted a status analogous to that of *possible worlds* within some versions of modal realism. A past/possible world has one *form* of reality, which allows for it to ground truths and underpin language, but it is not the same

[18]Well, empty of *objects*, at least. Both suggest that other things (e.g. simple facts, trajectories) might exist in the past even if objects do not.

form as the present/actual world.[19] Finally, one might even propose that past objects could simply exist within presentism. Some have argued that such a theory could still be considered presentist, provided that a certain emphasis or privilege was afforded to the present. Q. Smith (2002) raises a view where non-present things exist to a lesser *degree* than present things, while Baron (2015b) discusses a position where nonpresent things exist *in virtue of* present things. Presentism might be defined a little differently here, as the theory that only present things exist *simpliciter* or to the highest degree, allowing for nonpresent things to enjoy some form of 'second-order' existence.

I will have more to say about these four-dimensional 'presentisms' in §2.4. Ultimately, I will argue that these theories should not be thought of as presentist at all. For now, it is worth noting that whether one takes the term 'times' to literally refer to times or not, both camps of presentists employ a similar tactic for understanding temporal language in general. The presentist defines temporal language in terms of whatever entities there are that at least *represent* past times: entities that she *already* commits to in order to answer the truthmaker objection. For some presentists, special properties, ersatz times, or tensed facts are drawn upon; for others, it is times proper that are drawn upon, but those times are only afforded a restricted ontological status. On the one hand, this might allow for presentism to be defined as something like 'only the present exists', since each presentist could define 'present' in line with her particular views about truth-making. Note, however, that presentists themselves would disagree about the meanings of these terms. One could only define presentism in this way if it was understood as a category covering any theory that, *by its own lights*, maintains that only the present exists - or equivalently, for other definitions that lean on 'times' rather than the 'present'.

[19]Parallels between modality and presentism are well-known, but presentism is usually affiliated with *actualism*, not modal realism. See Bergmann (1999), Sider (1999), and Deasy (2019a).

There are a couple of issues with this approach. Firstly, it is problematic for presentists to define their position using temporal language, without an agreed-upon standard for what that language means. Almost anyone could come up with a definition for 'present' so that, by their own lights, 'only the present exists'. One cannot usefully categorise all of these views under the label of 'presentism', however, since there is little assurance that they share anything meaningful in common. If an eternalist were to believe that, in addition to their other properties, everything in the four-dimensional universe happened to have a property called 'presentness', then she would agree that only present things exist. Would that make her a presentist? This approach casts the net of presentism too widely, and so fails to provide a useful categorisation. If at all possible, it would be better to define the view so that it at least approximately captures only those theories that are intuitively presentist, and where each presentist can agree that, even by *my* own lights, *your* theory is a presentist one.

Secondly, this approach fails to capture theories that deny that there is *anything* that 'times' or 'presentness' could be good representations of. In chapter 3 I will defend a view called *hard* presentism, wherein there are no truths about the past or future, and so there are no extra entities introduced to account for such truths.[20] While hard presentists may not *have* to commit to it, one way to understand this approach is that there is nothing that 'present' or 'times' could be good representations of, and so such language should be avoided in technical contexts. While this approach will have its controversies, it does generally seem inappropriate that one should *have* to commit to a particular understanding of terms like 'times' in order to understand presentism, when on the face of it the word 'times' invokes exactly the sort of thing that presentists do not believe in. While there may yet be a representative purpose for language of this kind, it

[20]This idea is also entertained by Ingthorsson (2019, pp. 61-63).

would be more appropriate for us to define presentism in a way that does not *assume* as much, and instead draws on terms and concepts that the presentist is more reliably going to accept. Otherwise, we risk defining presentism in a way that does not make sense to at least some presentists.

While I have by no means exhausted every view in the literature, a rigorous definition of presentism does seem to be elusive. The dominant approach has been to define it in a *positive* way, so that in the very act of defining their view presentists commit themselves to believing that entities bear some quality like *presentness*, or they exist at *times*, or they *sometimes* behave like so, despite not doing so *now*. This seemingly four-dimensionalist thinking is difficult for presentists to work with. In the next section, I will argue that presentism would be better defined in a negative way, as the theory that reality does not temporally extend, or that there is no temporal dimension. Such a definition might exclude those theories mentioned above that propose a restricted ontological status for nonpresent entities. I will return to this issue in §2.4.

2.3. Understanding presentism negatively

Presentism is a theory about time. Intuitively, it might seem to be a theory about what time *is*. There are a number of varieties of presentism, and we might think that they are united under a single banner, which is some positive claim about time. There are, however, some important reasons to doubt this idea. Firstly, the positive claims made by presentists vary considerably. I have already given some indication of this in the previous section, but a more rigorous assessment has also been provided by Tallant and Ingram (2021). Their conclusion is different from my own, and I will have much more to say about it in §2.4, but at the very least they make a compelling case that presentists are not obviously united around any positive thesis that has yet been proposed.

Secondly, there is a degree of mystery in how presentists positively understand time. Presentists believe in *temporal passage*, which is meant to allow for *change* despite only the present existing. If presentists were united around a claim about how time is, then we might expect them to be united around a claim about how passage is. Yet this is not obviously so. The definitions above do not explicitly refer to passage, and while some presentists do attempt to describe passage in detail,[21] others merely gesture at it using a variety of metaphors and intuitions.[22] While further details about passage might be *interesting*, it would seem to me that presentists already feel that their view is distinct from its rivals, even *before* they make any specific claims about passage.[23] I am therefore doubtful that it is a *positive* claim about time that defines presentism. Rather, I believe presentism should be understood as a *negative* claim, about how reality *isn't*, or what time is *not*. Specifically, I believe that presentism should be defined as the negation of topological four-dimensionalism:

(¬T4D): no temporal topological dimension(s) exist.

If we are happy to assume that reality has exactly three spatial dimensions,[24] and that if no temporal dimension(s) exist, then there must *only* exist spatial dimensions, then (¬T4D) implies that our world is simply three-dimensional.[25] As (¬T4D) does not explicitly refer to the number of dimensions, however, it generalises to possible worlds with different numbers than our own. I will still refer to (¬T4D) as the negation of *four*-dimensionalism, to capture its implications for the world that we live in. I will also assume that (¬T4D) is equivalent to the theory that reality does not temporally *extend*.

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[21] I will return to this issue later in the section, but as indicated in §1.3.1 I will not address it in detail in this thesis. For discussions elsewhere see Prior (1962) and Markosian (1993).

[22] For more on these turns of phrase, and a critique of passage, see D. Williams (1951).

[23] For more on passage, particularly in light of the sciences, see Norton (2010) and Ismael (2017).

[24] Some frontier theories of physics (e.g. string theories) deny this. See Zwiebach (2009, pp. 7-9).

[25] Such a world might have the topology of a Riemannian three-manifold, with signature (+++).

As I noted in §2.1, most presentists would take their view to *imply* that the world is three-dimensional. So (¬T4D) does not *contradict* most presentist views. Beyond that, however, I would argue that it captures the most important underlying intuitions associated with presentism. Adopting (¬T4D) means committing to the belief that the past and future are not *out there*, they are not locations that one could in theory travel to. Objects, including people, are not four-dimensional 'worms', but are instead three-dimensional as we intuitively perceive them to be. In general, most theories of presentism would only *extend* on (¬T4D) by adding particular ontological commitments that, while perhaps useful for purposes such as truthmaking, are not thought to be *essential* to presentism. So whatever *is* essential may indeed by captured by (¬T4D). In §2.4 I will consider some exceptions: theories that invoke a temporal dimension, but which have nonetheless been called presentist in the literature. First, however, I will examine whether (¬T4D) avoids the pitfalls of the views discussed in §2.2. Does it implicitly commit to anything that is difficult for presentists to make sense of? Answering this question will require an assessment of how 'exist' and 'temporal topological dimension(s)' might be understood in this context.

Let us begin with 'exist'. In §2.2 I noted that a tensed reading of 'exist(s)' renders claims like 'only the present exists' either trivially true, or obviously false. It is also unlikely that one could take a temporal *dimension* to exist in a tensed way, so if presentism is defined as (¬T4D) then a *tenseless* 'exists' might still be required. Many of the presentist's rivals require the same: within eternalism and the growing block, for example, there is a tenseless sense in which past and/or future things exist. From all camps, then, come suggestions as to how tenseless existence might be understood. One popular approach is to use unrestricted quantification, so that something tenselessly exists if our widest *quantifiers* include it.[26] Another is to draw an analogy with modal realism, by taking existence in the past or future to be akin to existence in possible worlds.[27]

These notions of tenseless existence have faced criticism. Lombard (2010), for example, allows that we might *define* a 'master class' containing everything, where 'everything' can extend beyond the *now* if we postulate that 'if a class S exists at a time t, then everything that is a member of S exists at some time or other' (p. 59). It would be worrying, however, if debates about presentism reduced to mere worldplay about the rules governing classes. This talk of 'widest quantifiers' at least *obscures* the meaningful differences between a world where Aristotle tenselessly exists, and a world where he does not. We might seem to be arguing about how philosophers should write 'Aristotle' into their paperwork, rather than arguing about Aristotle *proper*. I would suggest, however, that tenseless existence is more robust than this. We can conceive of what it would mean for Aristotle to be *out there*, and we are assisted in doing so when we read time travel stories, or modern physics texts, which challenge us to consider the parallels between time and space. A time traveller would typically be thought of as travelling to times past while *leaving behind* a real present. If the world does not temporally extend then this has the tangible consequence that time travel, so conceived, is impossible.[28] While there is more to be said on tenseless existence, I would suggest that the use of it in (¬T4D) should not discourage us from adopting this definition, over the others on offer.

Next, consider 'temporal topological dimension(s)'. A temporal dimension is a distinctly non-presentist creature, and so on this matter the *negativity* of

[26]For a detailed defence of this position see Sider (2006). See also Correia and Rosenkranz (2020), who advocate for using such quantification *in lieu* of any talk of existence.

[27]For examples of this anology see Hinchliff (1996), Sider (1999, p. 326), and Deasy (2019a).

[28]The *form* of this impossibility will depend on whether this dimension is *necessarily* unreal. Other forms of 'time travel' might be compatible with presentism, but they could involve the suicide of the traveller, or the mass-murder of those 'left behind'. I return to this in §6.2.1.

(¬T4D) is crucial. The definitions discussed in §2.2 make implicit commitments to presentness, or times, and it is from those positive commitments that troubles come. Such presentists cannot draw on *other* temporal theories: they need to clarify what times are *within* a presentist world. By contrast, (¬T4D) does not implicitly commit to a temporal dimension within a presentist world. One can therefore draw on other theories of time, and the definitions they provide, when clarifying what it is that presentists deny. A temporal topological dimension is something proposed by eternalists, and other A-theorists, and so it is *their* charge to define what such a dimension would be like.[29] The presentist merely listens to their accounts, and finds herself unconvinced, which does not involve committing to anything problematic within her own ontology.

It would even be acceptable if eternalists *failed* to define a temporal dimension. It is unclear what a married bachelor would be, for example, but this does not undermine the claim 'married bachelors do *not* exist'. Quite the opposite: we doubt that married bachelors exist in part *because* they seem nonsensical. Similarly, if 'temporal dimension(s)' should turn out to be nonsensical then this only lends credence to the view that no such dimension(s) exist. This line of thinking might assist those who argue that presentism is *necessarily* true, though I am uninclined to go this far.[30] I grant that eternalists can provide a reasonable account of what a temporal dimension might be, as distinguished from spatial ones.[31] Yet I am a presentist, just because I am unconvinced that there exists a dimension of the kind that they describe.

There are two further points worth noting about (¬T4D). Firstly, with this definition settled upon the presentist could now define terms like 'present' and

[29] A large part of this task would be to clarify how such a dimension would differ from a *spatial* one, if it existed. See Skow (2007) on the distinctions between time and space.

[30] I discussed this in chapter 1. See also Ingram and Tallant (2018, sec. 1).

[31] Callender (2017, ch. 6) summarises some differences, beginning with those found in physics.

'times'. They will merely represent other things: the presentist does not *believe in* substantive times or presentness properties. If one still wishes to use these terms, however, then 'the present' could be defined as 'all of concrete reality'. Other terms might be defined in terms of other commitments: ersatz presentists, for example, might define the *present ersatz time* to be a set of propositions about reality, and nonpresent ersatz times to be sets of propositions bearing earlier- or later-than relations to the present ersatz time. 'Times', 'the past', 'hours', 'always', and 'sometimes' could then be defined using ersatz times. It is important that presentism was already defined as (¬T4D), and some clarity given to the presentist's view, before any attempt was made to define these terms. Taking 'the present' to mean 'all of concrete reality' would not be sensible without it already being established that reality is not temporally extended. By defining her language in this way, the presentist could interpret a claim like 'only the present exists'. I suspect that any sensible approach would yield the conclusion that, within presentism, only the present exists. This is only *implied* by presentism, however: it is not the *definition* of it. It is also likely that this temporal language, while useful in many settings, could be misleading in some formal contexts, as it merely represents other, more fundamental concepts.

Secondly, (¬T4D) leaves much unanswered about the details of any given presentist's worldview. Importantly, it does not specify why there seems to be some sort of thing called *time*: why there is change, movement, temporal phenomena of some kind. So silent is (¬T4D) on this topic that it classifies as presentist the view that reality is three-dimensional and *unchanging*. This does not strike me as a problem: with no existing past or future, such a 'frozen' world does seem to be presentist. Assuming that no one would wish to defend such a view, however,[32] we can take it that presentists must defend some account

[32]Parmenides might have done so, though as indicated in chapter 1 it is unclear if his view was three-dimensional. For more on his position see Copleston (1953, pp. 47-53).

of *temporal passage*. Different presentists will understand passage in different ways, and the success of their theories will in part depend on how convincing those accounts are. As noted in §1.3.1, passage is a thorny issue for presentists,[33] and not one that I will be solving here. There are, however, several approaches that presentists could investigate which are consistent with ($\neg$T4D).

Firstly, while presentists could define passage with reference to 'times', such language would be dispensible: they would really be defining passage in terms of ersatz times, or tensed facts, or the like. Drawing on truths and truthmaking entities is a fairly traditional approach. Prior (1962), for example, understood passage in terms of the changing tenses of true propositions.[34] If that won't do, one could instead define passage by proposing that objects bear *vector properties* associated with each way that they can change.[35] The term 'temporal passage' could be understood to refer to all vector properties collectively. I indicated in §1.3.1 that *primitivism* about passage might be a good course for presentists. Perhaps temporal passage cannot be analysed in terms of anything more fundamental: the world is three-dimensional, it *simply changes*, and somehow that does not imply the existence of a fourth dimension, or of any *times*. While there is obviously more work to be done here, I would suggest that defining presentism as ($\neg$T4D) does not make the problem of passage any *more* difficult than it would otherwise be. ($\neg$T4D) only excludes explanations of passage that invoke temporal dimension(s), and explanations of that kind would likely undermine the presentist's other beliefs anyway.

In this section I have proposed that presentism should be understood as a theory about what time is *not*, rather than as a theory about what time *is*. The

[33] See, for example, Dainton (2011, pp. 412-414) and Leininger (2015).

[34] Markosian (1993) defends something similar: changes in tense entail changes in A-properties, producing 'pure passage'. See van Cleve (2011) for a comparison of this view to Prior's.

[35] See Bigelow and Pargetter (1989).

(¬T4D) definition I support would often be thought of as an *implication* of presentism. I have argued that it should be thought of as its *definition*, particularly in light of the shortcomings of those definitions defended elsewhere. In the next section, however, I consider another shortcoming that could threaten my definition just as seriously as it threatens the others.

2.4. Pessimism towards defining presentism

Tallant and Ingram have recently argued that there is 'no theoretical core to presentism' (2021, p. 1). Their methodology is as follows: they identify a large variety of views that have been called presentist in the literature, and list fifteen candidate definitions of presentism that capture at least some of those views. They then argue that there is no definition or 'theoretical core' consistent with *all* of the views listed. So whenever one suggests a definition for presentism, one excludes at least some theories that have been called presentist in the literature. Tallant and Ingram consider, and reject, reasons for prioritising some of the so-called 'presentisms' above others. They conclude that attempts to formalise the definition of presentism are misguided. Every candidate definition considered by Tallant and Ingram is a *positive* one. As it had not been defended before, they of course do not consider the (¬T4D) definition.

Tallant and Ingram's argument is compelling. I agree that the term 'presentism' is, and perhaps always has been, applied to a wide and inconsistent variety of views. As I see it, there are two paths that the philosophical community might take from here. The first is to *give up* on defining presentism, as Tallant and Ingram's argument would suggest. The term 'presentism' might be relegated to the role of loose gesture, suitable only for idle chat in the tearoom, or as a guide when introducing students to basic metaphysics. We might expect more advanced students to avoid the term, however, and we might similarly avoid it in formal writing, in favour of more precise terminology. A second option available to us, however, is one of *conceptual engineering*.[36] We might accept that the philosophical community has failed to clearly define presentism *so far*, but respond to that confusion by steering the community towards a definition that is more useful. We might view the inconsistencies in the use of 'presentism' not as a sign that the term should be avoided, but rather as an anticipatable teething issue for a phrase that is still establishing itself in the lexicon of the modern philosopher. Instead of warning advanced students to avoid the term 'presentism', we might instead warn them that older texts use 'presentism' in a fairly loose way, prior to the community settling on a consistent definition.

I believe there are advantages to this second path, even if there is a certain arbitrariness in our ultimate choice of definition. With so many temporal views out there, it makes sense to engineer methods of categorising them, and when so many find 'presentism' to be a useful term in the lecture room there is a natural desire to carry that terminology over to formal writing. So there is intuitive appeal in steering the community towards a clear definition of presentism, even if such a definition is currently lacking. If the reader finds themselves swayed by Tallant and Ingram's arguments, then I invite them to consider a negative definition of presentism not because it arises 'naturally' from some shared core belief held by presentists, but rather for the more pragmatic purpose that it can aid us in our discussions moving forward. All we might ask of a definition is that it includes *many* of the views called presentist in the literature; that it satisfies *many* people's intuitions about presentism; and that it *works*, in the sense that it avoids the problems that positive definitions of presentism are troubled by. To that end, I would suggest that there are still good reasons to adopt the (¬T4D) definition. In the rest of this section, however, I will make a stronger

[36]For more on conceptual engineering see Isaac (2020) and Chalmers (forthcoming).

argument: I believe there might be good grounds to prioritise some so-called 'presentisms' over others, unlike Tallant and Ingram claim. In particular I will argue that theories that contradict (¬T4D), but which have been called presentist in the literature, might be rightly classified as non-presentist theories of time.

In §2.2 I discussed several views wherein only the present exists, but there is in some sense a past and future. To say that a fourth dimension *exists* within these theories might be too simplistic. Within some approaches, the dimension does exist, but the nonpresent times located along it are either *empty*, or exist to a lower *degree*. Within other views, the dimension spans some things that exist, and some that do not. By adopting a Meinongian metaphysics, say, these theorists maintain that nonpresent things have temporal locations despite not existing. Do such views contradict (¬T4D)? Certainly it seems that some of them do. As I wish to avoid delving into the sort of *being* that nonexistents might have within Meinong's jungle, I will assume that *all* of these views are excluded by (¬T4D), and so are excluded from the presentist camp.

While these theories might be perfectly workable in their own right, I do not believe that they should be understood as *presentist*, and so I am content to define presentism in a way that excludes them. I have two reasons for holding this view. Firstly, the notion that the past is *out there*, unseen but existent (or close to it), stretched along a fourth dimension that is conceivable in theory but invisible in practice, seems to me to directly violate the basic intuitions that presentism is founded upon. Even if the past is *empty*, or even if it only enjoys a *second-order* existence, there still seems to be a genuine sense in which these theories posit an extensive four-dimensional universe, in a similar fashion to the eternalists. While such theories might address some of the presentist's problems, such as the truthmaker objection, they are also likely to lack some of the supposed virtues that presentists seek: a simpler ontology than eternalism, say, or a closer correspondence between ontology and intuition. So while these theories might have *one* of traditional features of presentism - only the present exists *simpliciter* - they fail to satisfy many of the intuitions surrounding presentism, as well as many of the *aims* that motivate presentism. I am hopeful that the reader might share some of my intuitions about what presentists believe and aim for. We must bear in mind the lessons from Tallant and Ingram (2021), however, who rightly question whether these intuitions about presentism are universal. On its own, this first reason for excluding these views is likely insufficient.

Secondly, however, I suspect that these views could be more comfortably classified as moving spotlight theories (MSTs), introduced in §1.1.1. A four-dimensional ontology with a 'spotlight' appeals to the intuition that while there are *many* times (in some sense), the present is objectively privileged. This seems to be exactly the view that four-dimensional so-called 'presentisms' appeal to. There is also a fair bit of room within MSTs to understand this *privilege* or *highlighting* of the present in a number of different ways. Within a minimal version, for example, the spotlight might only be associated with a single property, *being present*, that objects gain and then lose in succession.[37] Deasy (2015) and K. Miller (2019b) argue, however, that there is reason to think that the spotlight could alter a larger number of an object's properties. We might think that as the spotlight moves across an agent, for example, it alters not only that agent's *presentness*, but also some of the *mental* properties of that agent.[38]

If the spotlight's movement over a time could alter various different features of the things contained within it, then there is room to propose particular MSTs where the spotlight alters features relating to *existence*. I would suggest that the four-dimensional 'presentisms' from §2.2 could be understood as theories

[37] I discuss this characterisation of MSTs further in §4.3.1.

[38] This idea is drawn on to respond to the *epistemic* objection, flagged in fn. 26, §1.1.1. For more on this response see Forrest (2004) and Heathwood (2005).

of this kind. If there was a four-dimensional universe with a moving spotlight, and that spotlight altered whether an object had the *property of existence*, then we would have Meinongian 'presentism'. If instead the spotlight altered grounding relations, such that every object outside of the spotlight was in some sense *grounded* by those things within, then we would arrive at a theory were only the present exists simpliciter, but other things exist *in virtue of* the present. We could just as easily suggest a theory where the spotlight alters the *degree* of an object's existence. Finally, the spotlight's arrival at a time could somehow make that time become momentarily populated with objects.[39] Many times exist, in this view, but all nonpresent times are *empty*. Overall, I would suggest that these four-dimensional 'presentisms' should be classified as MSTs instead, and so I am comfortable defining presentism in a way that excludes them. I do not mean to insult these theories by classifying them in a different way. They might be perfectly reasonable MSTs, or failing that, perfectly reasonable theories fitting neither into presentism, nor the moving spotlight. Regardless, I consider any view where nonpresent times are *out there* to be fundamentally at odds with presentism. The definition I propose is built to capture this intuition, elevating it to be presentism's *essential* characteristic.

A final view to consider is the theory that only the present exists, but it is *thick*, with a nonzero temporal width.[40] On the one hand, if the present had a large width - a day, say - then that would contradict ($\neg$T4D), but such a view would not intuitively be presentist either. At the other extreme, the width of the present might be very small: we can even consider a present that is *atomic*, spanning only a single *quantum* of time. Such a view is intuitively much closer to presentism, but it is also less obvious whether it violates ($\neg$T4D). Would a

[39] Explaining *how* this occurs is a serious issue, whether the theory is classified as a MST or not.

[40] For views of this kind see Hestevold (2008) and Baron (2012).

quantum of time have any extension? Would it invoke a fourth dimension? Even if these questions are difficult to answer, they do not undermine (¬T4D) as the arbiter by which we determine which views are presentist. It is not startling to find views that are *nearly* presentist, but not quite; nor to find views that are similar enough for it to be *vague* as to whether they are presentist or not. One can anticipate 'close calls' for any definition of any philosophical theory. Yet, I would suggest that (¬T4D) continues to serve as a good compass for making judgements about such views. After all, if a theory seems *close* to presentism, it might well be because it posits temporal extension that is *close* to nonexistent.

2.5. Conclusion

I have argued that a negative definition of presentism is superior to the positive definitions defended elsewhere. Rather than attempting to define presentism using terms that the presentist herself, arguably, does not make room for (such as 'times'), it would be better to define presentism as a denial of temporal extension, or temporal dimension(s). Though I think there is a good case to be made for this negative approach, I do not regard it as settling the debate over whether presentism should be defined precisely at all. Once we have a clear idea of the best available definition of presentism, we can better consider whether steering the community towards adopting that definition is the best way forward, or whether we should instead resign to thinking that, as Tallant and Ingram put it, such a scheme can provide 'no pay-off' (2021, p. 21). For my own part, however, I am inclined to believe that there *is* a pay-off, and that a negative definition of presentism can deliver where other, positive definitions have failed. For the rest of the thesis I will assume that presentism should be understood in this way.

Chapter 3: Presentism and Truthmaking

Abstract

One of the most serious criticisms facing presentism is that it might be incompatible with any acceptable system of truthmaking. If there is no past, how could there be truths *about* the past? In this chapter I introduce a new theory of presentism, which addresses this problem in a novel way: by simply denying that there are any truths about the past. While *prima facie* unintuitive, I argue that a sensible presentist philosophy of this kind can be described, as long as it is accompanied by an appropriate system of *physics*. I also briefly explore how this view could allow us to interpret fundamental physics in new and interesting ways.

3.1. Introduction

In this chapter I introduce a new philosophy of time, *hard presentism*. I then defend that philosophy by outlining some important links between presentism and fundamental physics. I will prioritise the philosophical questions facing hard presentism, so discussions of physics will mostly be limited to that which is essential for describing the theory. With that said, one of the attractions of hard presentism is that it may open up new opportunities for interpreting quantum mechanics. This is a possibility that I will nod to here, and then explore in more detail in chapter 5. In §3.2 I will outline the truthmaking objection to presentism, and indicate the new angle that my own theory takes with respect to that problem. By the end of §3.2, it will be clear that the hard presentist has some issues to address if she is to provide an intuitively acceptable answer to this objection. In §3.3, I will show how these problems of truth and intuition can be recast as a problem for presentist physics. This will pave the way for a discussion of that physics, and the solutions it provides, in §3.4. I then respond to some of the main metaphysical objections to hard presentism in §3.5. Before I begin, there are two initial issues worth mentioning.

Firstly, it is worth acknowledging the objections based on physical science that presentists already face from outside of the field of quantum mechanics. Physicists often model the universe using relativistic *spacetime*. Within that framework, key features of presentism are missing: there is no objective present time, and no robust temporal passage. In chapter 1 I introduced *eternalism*, a temporal ontology that closely matches this spacetime structure. The eternalist proposes that all entities throughout time exist within a four-dimensional *block universe*. While the eternalist might talk of 'change' by comparing one part of the block to another, the block as a whole undergoes no change, with all future events already existent and fixed. Presentism, on the other hand, is sufficiently different from this four-dimensional picture that it stands accused of outright contradiction with relativity theory. Whether presentism or other A-theories can or cannot be defended from these objections will be addressed in chapter 4. In the meantime, the discussions of physics in this chapter will be limited to non-relativistic quantum theory.

Secondly, it is worth warning the reader that hard presentism does clash with some of our basic intuitions about truth and the past. Many readers may only be inclined to take the theory seriously once it has been introduced in full, since particular links between presentism and physics must be spelled out before these intuitive concerns can be properly addressed. I leave most of the discussion of these problems to §3.5. With that said, my discussion of truthmaking in §3.2 should clarify why presentists might be tempted to explore some new, unintuitive approaches to truth, and by the end of the chapter I hope to have presented a theory that successfully navigates that possibility.

3.2. Presentism and truthmaking

It is generally acknowledged that there must exist a close connection between truth and ontology.[1] This connection is often thought to take the form that truth *supervenes on* being: that which does or does not exist must determine which statements are or are not true.[2] This principle serves presentists well enough when considering the present, since the present exists, and truths can follow from that. The truthmaking objection to presentism is the claim that presentists are unable to account for true statements about the past.[3] The intuition behind this objection is clear enough: if the past does not exist, then past truths cannot supervene on being in the same fashion as present truths.

There have been two main lines of response from the presentists. The first approach, known as *upstanding* presentism, is to propose some kind of presently-existing entity that grounds truths about the past. The second approach, known as *nefarious* presentism, expands the principle of truthmaking in a manner that allows for some statements to be true independently of that which exists. Both of these approaches look to retain an intuitive set of true statements about the past. I will briefly examine each, and the objections that they have faced, before considering approaches to presentism that do *not* retain those intuitive truths.

[1] There is a related question concerning what truths themselves *are*. I will assume that *statements* are the bearers of truth-value, but the same arguments could be made of propositions, beliefs, etc. I am inclined to understand truths loosely in terms of language or semantics, rather than as abstract existing *things*, but this will not be important for the arguments made here. For more on theories of truth and debates about ontology see Ramsey and Moore (1927), Field (1972), Grover, Camp, and Belnap (1975), Walker (2017), Ray (2018), and Shieh (2018).

[2] See Baia (2012), Fine (2017), and Cameron (2018).

[3] Similar problems arise for truths about the future, under presentism or the growing block. See Briggs and Forbes (2010). There has been debate about whether there are such truths ever since Aristotle's sea battle in *De Interpretatione*, so it will be most instructive to focus here on the past.

3.2.1 Upstanding presentism

Within upstanding presentism, a statement like 'Ceasar crossed the Rubicon' is true, but not because Ceasar and the Rubicon exist 'out there' in the past. Instead, it is true because of presently-existing *proxy entities*, standing in for Ceasar and the Rubicon within the truthmaking process. For a start, presentists might claim that the everyday physical present grounds truths about the past, a position known as *reductive* presentism.[4] While past truths would seem to be connected in some way to presently-existing things, and particularly to things like records, evidence, and memories, the claim that the former are *made* true by the latter can lead to some intuitively strange results. For example, it would seem problematic to think that 'I had porridge for breakfast' is true *because* there exists an apparent memory of porridge in my head. If anything, the explanatory arrow would seem to run in the opposite direction: I remember breakfast *because* I truly ate it.[5] It might also be the case that different possible pasts could have led to the same physical state of affairs today. The everyday present therefore only contains broken *information* about possible pasts, which is handy enough in practical life, but which cannot provide the kind of one-to-one grounding needed to produce a single set of determinate past truths.[6] So when it comes to past truthmaking, the present alone won't do: the upstanding presentist must instead look to abstract alternatives.

Many abstract proxy entities have been advocated for: Lucretian properties,[7]

[4]So called by Bourne (2006b). Keller (2004) attributes this view to St. Augustine.

[5]Caplan and Sanson (2011, p. 202) discuss similar problems for other upstanding presentisms.

[6]I will discuss in §3.5.1 whether the everyday present might be sufficient to ground some broad *indeterminate* truths about the past, for example 'there was a past'.

[7]Properties like 'being a universe where Ceasar crossed the Rubicon', held presently by the universe itself. This position has roots among the Greek stoics: see Bigelow (1996).

thisness properties,[8] temporal distributional properties,[9] and ersatz times,[10] to name a few. Most of these options run into a pair of similar criticisms. Firstly, these abstracta are accused of being too unusual or 'dubious' to be acceptable extensions to our ontology.[11] At the very least, these seem to be *worse* ways of extending our ontology than proposing that the past exists, since the concrete existence of past entities may be a more acceptable form of being than we can grant to these abstract proxies. Secondly, upstanding presentists are accused of violating the *aboutness* principle: that is, that truths must be grounded by the entities that those truths are about.[12] The critics claim that the introduction of proxy entities reduces our claims about the past to mere claims about present abstracta, or in the reductive case, to mere claims about the concrete present. In either case, it is not obvious that something other than a past entity can make a statement about a past entity true.[13]

3.2.2 Nefarious presentism

The nefarious presentist argues that statements about the past are capable of being true independently of that which exists.[14] To allow for this, she proposes a principle of *tensed supervenience*, which allows for a statement to be true in virtue of that which exists, or in virtue of that which exist*ed*.[15] To say that an object

[8]Properties like 'being Ceasar', also known as *haecceities*. This property comes into existence with Ceasar but lingers afterwards, haunting the universe to this day. See Ingram (2016; 2019).

[9]Properties like 'being Ceasar-then-being a corpse-then-being dust', held presently by the dusty remains of Ceasar. See Cameron (2011). See Corkum (2014) and Tallant (2014b) for critiques.

[10]Sets of propositions pertaining to a particular time. All of these propositions are said to exist themselves as abstract entities. See Bourne (2006b) and Crisp (2007).

[11]See Caplan and Sanson (2011). Tallant and Ingram (2015) claim that this unhappy ontology always makes the upstanding approach less preferable than the nefarious approach.

[12]This objection is covered in detail by Baron (2013a).

[13]Dolev (2010) claims that some upstanding approaches lead to a problematic 'double meaning' of truth, if present truths satisfy the aboutness principle, but past truths do not.

[14]For a summary see Baia (2012).

[15]See Heathwood (2007) for a critique of this principle.

exist*ed* is not claiming its existence at some prior location in four-dimensional spacetime. So what does it mean, exactly? Nefarious presentists can be reluctant to clarify this point, claiming that the tensed language invoked here is primitive and unanalysable. 'Caesar crossed the Rubicon' is true simply because Caesar crossed the Rubicon, and that's that. It would seem that 'Caesar crossed the Rubicon' is in some sense true *now*, however, and so it makes sense to wonder what it means *now* when we say that Caesar crossed the Rubicon. Is there any tangible difference between a world with, and a world without, this tensed fact? There are two plausible answers. Firstly, *Meinongian* presentists describe objects that exist*ed* as having some sort of being that is less than existence, but more than fiction: a category of their own for things that merely *were*.[16] This could arguably be thought of as an upstanding position rather than a nefarious one, since this new category of being looks very similar to a category of truthmaking abstracta. Accordingly, the Meinongian presentist falls foul of the same critisms of 'dubiousness' that were laid at the door of the upstanding camp.[17]

The second, properly nefarious position is to deny that objects that exist*ed* have any form of being at all.[18] In this case, it seems misleading to claim that past truths are 'made true' by that which exist*ed*, since there is no such thing to do that work. The principle of tensed supervenience may in this case be reducible to the claim that past truths are made true by *nothing*.[19] There is no difference between a world where 'Ceasar crossed the Rubicon' is true, and some other possible world where it is false, other than the brute fact that Caesar *just did* cross the Rubicon. This abandonment of truthmaking for nonpresent

[16]See Baron (2015a) for an overview. The 'brute past' theory of Kierland and Monton (2007) would also likely fit into this category.

[17]A Meinongian metaphysics is one where there *are* objects that do not *exist*. Criticisms of that general metaphysics will apply to the presentist case. For a defence see Paolini Paoletti (2016).

[18]See Merricks (2007, ch. 6-8) and Tallant and Ingram (2015).

[19]If 'made true' means that truths bear grounding relations, then it is concerning that those relations do not have any relata, other than truths themselves. See Baron (2013b).

times could be problematic, since we could imagine a universe where in one moment, Ceasar is crossing the Rubicon, and then in the next moment, it *just is* a fact that Ceasar did *not* cross the Rubicon. If past truths are not made true by ontology, then there is no obvious way to ensure that the set of brute facts about the past properly matches up with events after they occur.[20] Further, some critics have claimed that past truths necessitate at least *some* features of the past, even if the past does not need to exist. For example, there might need to be some *relations* between past things and present things, but it is unclear that relations are capable of holding between present entities and *nothing*.[21]

Either approach to presentist truthmaking breeds a similar sort of concern. The presentist cannot ground an intuitive set of past truths without invoking some extension to her ontology, but the suggested extensions are all *weird*, and therefore presentist theory is at best unparsimonious, and at worst incoherent. I will not delve into the arguments about these established theories of presentism in any further detail here. It will be sufficient to note that these criticisms, along with the aforementioned objection from relativity, have left few philosophers referring to themselves as presentists today.[22] Indeed, similar arguments have been raised against any theory that objectively differentiates the present from other times, turning many in the community away from the entire notion of an objective or absolute present.[23]

[20] Leininger (2015) makes a similar point using a 'One Instant Test'. If God created the universe as it exists now, out of nothing, then it would contain the same proxies that the upstanding presentist advocates for, or the same brute facts that the nefarious presentist advocates for. But there should not be any past truths, in this one-instant universe!

[21] See Asay and Baron (2014), who also claim that nefarious presentism cannot account for past negative existentials, such as 'there have been no unicorns'.

[22] The popularity of presentism among modern philosophers was addressed in §1.1.3.

[23] K. Miller (2017), for example, argues that non-presentist *dynamic* temporal theories face an even harder challenge when accounting for truthmaking than presentism does.

3.2.3 Hard presentism

There is another approach available to presentists: to deny that there are any true statements about the past or future at all. I call this stance *hard presentism*.[24] The hard presentist can accept that truth supervenes on being, and that only the present exists, without introducing any unusual abstracta into her ontology. The hard presentist has none of the usual troubles with truthmaking, since she simply denies that there are any past truths that need accounting for.[25] She exchanges this problem, however, for a new one: she must deny the basic intuition that there just *are* past truths.[26] Whether this clash with intuition alone makes hard presentism *prima facie* unacceptable is explored in §3.5. For now, I will assume that this view is defensible if, and only if, the hard presentist can explain how people might come to intuitively believe in past truths, and why these beliefs are pragmatically useful. If there are no truths about the past, why do there *seem* to be truths about the past? I regard this as one of the most significant problems facing hard presentism, and the next two sections will be dedicated to addressing it. In §3.3 I will show that, in general, a theory of *physics* could explain where these intuitions and beliefs come from, provided that that theory contains some appropriate features related to determinism and indeterminism. I will then demonstrate in §3.4 that there are appropriate theories of physics of this kind that the hard presentist can adopt. The aim of this chapter, then, is to introduce a theory of presentism that avoids the truthmaking problems that plague other presentist theories, while at least *accounting* for our intuitions

[24] In §3.5.1 I will consider whether hard presentists might believe in some *indeterminate* past truths, grounded by the present. I consider this to fall within the purview of hard presentism, since it would still involve far *fewer* past truths than we might intuitively believe in. This should not matter a great deal anyway, since this will prove to be an unconvincing alternative.

[25] Though I am not inclined to do so, one could go even further: some have denied that there are *any* truths, strictly speaking. See Soames (1999, pp. 20-56) for a critique.

[26] Hard presentism is often dismissed in the literature for this reason. Keller calls it 'crazy' (2004, p. 88); Dummett calls it 'repugnant' (2004, p. 44). For an exception see Ingthorsson (2019).

about truth, even if the theory disagrees with those intuitions on a fundamental level. While the structure of the rest of the chapter will largely focus on the *problems* facing hard presentism, what will emerge from those discussions is not only that the hard presentist can overcome these problems, but also that the view has a number of *advantages* to offer when it comes to understanding truth, and when interpreting fundamental physics.

3.3. From truthmaking to physics

In this section I will argue that there could be no past truths, but nonetheless there would *seem* to be past truths, if reality was *indeterministic* on the micro-scale, but *approximately deterministic* on the macro-scale. This claim will take some unpacking. In §3.3.1 I clarify how determinism and indeterminism should be understood in the hard presentist context. I then argue in §3.3.2 that, if there were no truths about the past or future, then the physics governing our world would be fundamentally indeterministic. In §3.3.3 I show that there would *seem* to be past truths if macro-scale physics was approximately deterministic. The challenge facing the hard presentist by the end of the section will be to establish a believable system of physics under which approximate determinism *emerges* from an indeterministic fundamental theory.

3.3.1 (In)determinism in a presentist world

Let us briefly consider what the ontology of a presentist universe looks like. As established in chapter 2, presentists believe that concrete reality is merely three-dimensional, and by definition we call that reality 'the present'. I will remain agnostic on whether presentists believe in some entities (e.g. abstracta) that lie 'outside of time', rather than specifically being present. The important thing is that there is no temporal extension. Explicitly past entities, as well as future ones, are not *out there*. In order to avoid an ontology that is confined to a single, unchanging three-dimensional world, however, presentists must also believe in some form of robust temporal *passage*. I noted in §1.3.1 that passage is difficult to describe in a precise or noncircular fashion.[27] For now let us assume that passage can be defined without invoking the existence of, or truths about, nonpresent times. There simply exists some *evolving* three-dimensional objects. This notion of passage is instrumental when understanding the role of *physics* within presentism. Physicists are concerned with describing reality, including the way that reality evolves over time. Physicists often do this by appealing to natural laws, each of which constitutes a rule or limitation on how things can change.[28] Accordingly, every law of nature can be understood by the presentist as a law governing how passage works. To say that there is a natural law L is simply to say that passage exists in a manner described by L.

I wish to consider whether hard presentists should adopt (in)determinism. The notion of determinism I refer to here is often called *causal* or *nomological* determinism, though these terms can be misleading, since causal determinism is generally not defined with respect to causal relations, or to truths about which events caused which.[29] Rather, determinism is a view about how the laws of nature work, and about what the laws, along with the complete state of affairs at one time (i.e. the present), do or do not *necessitate*, or *imply*, or *determine*, or *logically entail*. Determinism is also generally not defined with respect to an

[27]See Deasy (2018a) for a summary of and defences against objections to A-theoretic passage. See also Norton (2010), who acknowledges that describing passage is difficult, but cautions against using this as a reason to disregard passage as unreal.

[28]The metaphysical status of these laws is a controversial topic. Certainly, the hard presentist cannot understand laws in terms of relationships between events at different times. As I discuss in §3.4.2, the hard presentist may simply have to treat passage as primitive, and then ground the laws in that primitive passage. I will not address this issue any further in this chapter, but for a summary, and a modern critique of laws, see Filomeno (2019).

[29]See Earman (1986, p. 5). I will follow the modern trend of simply calling this 'determinism', in line with basic resources on the subject such as Hoefer (2016).

existing past or future, or with respect to truths about them. As I will explore in §3.3.2, it might *follow* from determinism that there are truths about the future, but the initial definition of determinism merely involves the laws, the present, and what can be derived from them. To this end, it will be helpful to distinguish what *in practice* truly occurred or will occur, from what *in theory* the present could evolve into, or out of, given what exists now. To say that a state S could *in theory* have evolved into the present is simply to say something about the laws and the present; it is not to say that S exists,[30] nor that S truly occurred.[31]

We can then understand reality to be *deterministic* if there is just one unique way in which the present could *in theory* evolve, given the laws of nature are the way that they are. Mathematically, deterministic laws only provide one way to develop data from a given instant. Conversely, reality is *indeterministic* if there are multiple, mutually-inconsistent ways in which the present could *in theory* evolve. Mathematically, indeterministic laws provide several ways by which data from an instant can be developed, perhaps due to *probabilistic* terms within those laws. Note that, as I have defined it, indeterminism is a combination of both *under*- and *over*-determination: the present state could, in theory, evolve into a variety of future states, and out of a variety of past states.[32]

As I noted above, one way of understanding an indeterministic world is to posit that the laws of nature are *probabilistic*, such that some courses of system evolution are objectively more likely than others. I will discuss how the hard presentist understands objective probability in the next section. For now it will

[30]How can we make sense of S, if no S exists? We might adopt the terminology of Barbour (1999, ch. 2) who talks of each time (in this case, the present) as containing a *time capsule*, an intrinsic representation as of things occuring before and after. Ismael (2002) questions why Barbour does not believe in *one* time capsule, one existing moment. In a manner of speaking, this is exactly the hard presentist view. For more on Barbour's position see Butterfield (2001).

[31]Some readers might wonder whether the fact that S could *in theory* have evolved into the present might make it true that S *could* have happened in the past, which seems to be a truth *about* the past. I address such indeterminate past truths further in §3.5.1.

[32]For more on overdetermination specifically see Sider (2003).

pay to define *approximate determinism* as the scenario where reality is fundamentally indeterministic, but on a large enough scale there emerges a strong probabilistic preference towards one course of evolution, or towards a narrow set of similar courses of evolution. An approximately deterministic world will *appear* to be deterministic to those observers who cannot discern low-likelihood or small-scale indeterministic effects. It may be pragmatic for such an observer to assume and act as if the world is deterministic, even though it is not. This will be important when we consider why humans assume and act as if there are *past truths*, even if there are none.

3.3.2 Hard presentism and indeterminism

The hard presentist denies that there are any truths about the past or the future. Intuitively, this position seems to favour an indeterministic worldview, since both hard presentism and indeterminism treat nonpresent times as *open*, in at least some sense. If reality were deterministic, however, then the aboutness objection and the problems with explanation discussed in §3.2.1 would indicate that the present still could not *ground* truths about the past. There may also be a form of *openness* about the past that is distinct from what is determined by physics: consider for example *last-Thursdayism*, the thought experiment where the entire universe popped into existence last Thursday, complete with *deterministic* laws of nature. Whether this occurred is a question about the past that even deterministic laws, in combination with the present, cannot answer.[33] So perhaps there is room for the hard presentist to deny that there are any past truths, but nonetheless maintain that the laws are deterministic.[34] Although this position cannot be obviously ruled out, I still regard it as a very difficult

[33]See Barnes and Cameron (2008) for several arguments suggesting that nonpresent truths are distinct from determinism, bivalence, or even the existence of nonpresent things.

[34]This is emphasised in the discussion of hard presentism by Ingthorsson (2019, pp. 61-63).

position for the hard presentist to adopt. I would argue that indeterminism is a strongly *preferable* position for the hard presentist, for two main reasons.

Firstly, the hard presentist could be failing to take truth seriously if she claims that the laws only allow for the present to evolve from one past, and into one future, but nonetheless it is not *true* that that past occurred or that future will happen. '"The sun will rise tomorrow" is true' should mean more than the mere assignment of a truth-value to a statement, without any relevance to the rest of the world. Perhaps it should mean that the sun's rise tomorrow is certain, or unavoidable, or *fixed*, or something along those lines. If the hard presentist adopts determinism, then she might be admitting that claims about the future are indeed certain, unavoidable, or fixed, and so to nonetheless deny that those claims are *true* might be failing to take truth seriously. While determinism is not sufficient to *ground* truths about nonpresent times, worldviews containing the former but not the latter still seem to be problematic.

Secondly, adopting presentism could make indeterminism itself an easier position to maintain. I noted earlier that indeterminism might invoke a notion of *objective probability*, but many indeterminists have only been able to make sense of such probabilities by positing the existence of unusual modal entities, branching spacetimes, or possible worlds.[35] In §3.4 I discuss how indeterminism is understood within quantum mechanics. For now, it is worth recognising that while probability plays a major role in the mathematics of quantum theory, modern interpreters have often been reluctant to accept objective probability into their theories. Everettians avoid it; de Broglie-Bohm theorists generally do the same;[36] GRW theorists sometimes *attempt* to avoid it, with questionable

[35]See McCall (2009) for an example in the context of quantum mechanics.

[36]Bohm described quantum systems as 'determined by definite laws, analogous to (but not identical with) the classical equations of motion' (1952a, p. 166). While indeterministic versions have been proposed, as well as similar theories such as that of E. Nelson (1966), it is often regarded as a strength of the view that it *avoids* indeterminacy. See Callender (2007, p. 359).

effectiveness;[37] and QBists, content with an epistemic description of the wave function, remain agnostic on whether reality behaves probabilistically beyond our knowledge of it.[38]

The presentist's belief in *passage* allows for her to make sense of objective probability without these complications. To see how this works, consider a different approach to objective probability that avoids introducing possible worlds or branching spacetimes, that is the *propensities* approach.[39] Propensity theorists posit the existence of physical properties that give objects the tendency to undergo probabilistic change. Note the similarities between propensities, and the notion of *passage* that the presentist is already committed to. Though it is likely not a *property*, passage is also some physical feature of a system that imbues it with the tendency to change. Just as the propensity theorist establishes objective probability as a feature of propensities, the hard presentist can establish it as a feature of passage: no other properties or modal entities are required. Propensity theory has of course been criticised in the literature,[40] but there are some differences between propensities and passage that make the latter a more promising means of understanding probability. For example, a propensity is a two-stage property that is first *unrealised*, and later *realised*. Critics argue that propensity theorists cannot provide a straightforward causal mechanism by which a propensity can switch from one to the other. Passage, on the other hand, has no second stage: it is simply happening, and requires no causal mechanisms of this kind. Propensities are also unlike passage in that it would seem possible to understand them as existing *at a time*, separately from the changes that they create across time. Critics then point out that if we picture an object

[37]Frigg and Hoefer (2007) provide a summary of the limited options for GRW theory.

[38]For more on QBism see Fuchs, Mermin, and Schack (2014), Fuchs (2017), and Mermin (2017).

[39]First introduced by Popper (1959), and then adapted by others: see Gillies (2000).

[40]See, for example, the twenty-one problems discussed by Eagle (2004).

frozen at a specific time (an *object-stage*) then there is no clear physical feature of that object-stage that we can point to as evidence for it having a propensity. Temporal passage differs from this, in that it is not present when we picture an object 'frozen in time'. It is exactly the removal of passage that constitutes the difference between the object-stage, and the object as it actually exists. So the evidence for passage is more intuitive than the evidence for propensities.

Strictly speaking, then, the hard presentist's denial that there are any past truths does not necessarily commit her to indeterminism. However, the hard presentist will find indeterminism to be an unusually straightforward position to adopt, while determinism would be unusually difficult. Given that, I will assume for the rest of this chapter that the hard presentist supports a worldview that is indeterministic on the most fundamental scale.

3.3.3 Human experience and approximate determinism

Now I return to the question posed at the end of §3.2: if there are no past truths, why do there *seem* to be past truths?[41] I would posit that our beliefs about nonpresent truths are informed by our practices of *extrapolation*: we take what information we can access in the *present*, and use it to build a story of past and future events. I might believe that 'I ate porridge for breakfast' is true because I extrapolate it from the apparent memories of porridge presently in my head, and from the porridgy dishes presently in the sink.[42] I will avoid any serious discussion of human evolution or psychology in this section, by assuming that agents such as human beings would engage in retrodiction and prediction, and

[41]There has been some recent work on whether people might *not* believe that there are past truths, or at least whether the sentences we utter might not express as much, and express *non-cognitive attitudes* instead. See K. Miller (forthcoming).

[42]Or, strictly speaking, from the sensory experience I have *as of* seeing porridgy dishes. A person can only *presently* access information at her location, within her own brain, so even our sense experiences are a form of retrodiction. This is discussed further in §3.5.1 and §4.2.2.

base our beliefs on those practices, if doing so was pragmatically useful: if, for example, those practices and beliefs helped us to anticipate the effects of passage. I would also posit that these practices would be most useful to us if they gave us a fairly *specific* story of the past or future. I retrodict that I ate porridge for breakfast, and I might intuitively believe that to be true, because there is a fairly precise story of that kind that I can extrapolate from the present. I cannot and do not predict from the present anything specific about what a stranger might have for breakfast three years in the future, however, and so I am less intuitively inclined to believe in truths about that event.

Now consider how these practices of extrapolation would play out in an *approximately* deterministic world. An agent with *perfect* information about the laws and the macroscopic present B could extrapolate, *in theory*, a story of past and future events that would be tightly clustered around a specific macroscopic past A, and a specific macroscopic future C. In practice, agents such as humans work with very limited information about B, and at best a working theory, believed implicitly more than explicitly, about how the passage of time works. So we can expect the extrapolative practices of humans to often diverge from A and C. With that said, approximate determinism ensures three important things when it comes to the retrodictions and predictions made by humans. Firstly, it ensures that we could *plausibly* represent quite specific stories of A or C, if our powers of extrapolation were sufficiently strong, and if we were representing *simple* events from the *recent* past or future. Our powers of *retrodiction*, at least, might meet this standard, since we have access to time-asymmetric processes like memory formation that make retrodiction easier than prediction.[43] So we

[43]The hard presentist can readily explain why our apparent memories are past-oriented: it is simply possible to form mental states representing events that, in general, can be expected to change fairly little as a result of passage. Other more widely-acknowledged explanations, like the entropy-asymmetry of memory formation, could also be relevant. See M. Barrett and Sober (1992) for a discussion of the relationship between memory and entropy.

might expect that our retrodictions of basic events from the recent past would be tightly clustered around A. Secondly we expect that, the more information we consider, the more our extrapolations should approach a small cluster of possible pasts/futures, even for complex or distant events. In this context, our retrodictions and predictions would *appear* to be approaching a single, *true* account of the past and future. Thirdly, any significant disagreements between the extrapolations of different agents would be much more likely to be a result of faults on behalf of those agents, than to be a result of indeterminism.

In this scenario, there would *seem* to be past truths, at least to macroscopic agents such as human beings. Approximate determinism ensures that there is a sharp peak in the states that are likely, *in theory*, to evolve into or out of the present, and this would translate into a sharp peak in our retrodictions of the past. Any discrepency between this peak of possible pasts, and a single, determinate past truth, would be sufficiently small-scale or sufficiently unlikely that it would go unnoticed in our everyday lives. The steady convergence of our retrodictions, as we consider more and more information, would appear to us to support the notion that there are specific past *truths* that we are converging towards. It would therefore make sense for us to assume that our practices of prediction and retrodiction were practices in calculating *what the truth is*, not just practices in calculating what is or is not consistent with the present. The hard presentist can therefore explain why we intuitively believe in past truths, even though there are no past truths, so long as she can support a system of physics wherein the macroscopic world is approximately deterministic. On the face of it this is a trivially easy problem to solve, since it is accepted by physicists that the behaviour of the macroscopic world *is* approximately deterministic. As we saw in §3.3.2, however, the hard presentist supports a fundamentally *indeterministic* worldview, so she cannot explain the determinism we see on a macroscopic scale simply by declaring the world to be deterministic in general. The hard presentist instead needs to put forward a believable system of physics, wherein approximate determinism *emerges* on a macroscopic scale from a fundamental physics that is indeterministic. This is not a trivial exercise, but as I will show in the next section, it is certainly still an achievable one.

3.4. Hard presentist physics

The core purpose of this section is to show that there are acceptable systems of physics that the hard presentist can support, under which reality is fundamentally indeterministic, but macroscopic reality is approximately deterministic. Fortunately, many thinkers have already proposed interpretations of quantum mechanics that satisfy this requirement. Unfortunately, these interpretations often only succeed in describing reality in this way by committing to controversial or unintuitive ontologies. In §3.4.1 I will summarise these interpretations, and the challenges that they face. While adopting one of these theories could still be a viable option, there is also reason to be vigilant for new opportunities to interpret quantum mechanics in more intuitive indeterministic ways. I believe that hard presentism itself may open up opportunities of this kind. For that reason there is a second purpose of this section, which is to briefly explore what a new, explicitly presentist understanding of quantum theory might look like. Across §3.4.2 and §3.4.3 I will outline a toy model, which will exemplify the new options that hard presentism might allow for. I will revisit this subject in greater depth in chapter 5. §3.4.4 will detail how both the old and the new approaches to quantum theory give rise to approximate determinism on the macro-scale. In this area the toy model shows promise, since it may be capable of explaining approximate macro-scale determinism in a more straightforward fashion than those interpretations that have come before.

3.4.1 Established indeterministic interpretations

Quantum mechanics is, at its core, a probabilistic theory. While some argue that this probability is merely a sign that the theory is underdeveloped, or that it is merely an indication of what experimenters can *know*, I am not alone in feeling inclined to take this probabilistic character at face value, interpreting it to mean that there really is randomness and indeterminism in the mind-independent world.[44] Accordingly, there are several indeterministic interpretations of quantum mechanics, from the simplistic version of the Copenhagen interpretation typically taught in an undergraduate physics class, to more complete interpretations such as GRW theory,[45] Nelsonian Mechanics,[46] and the consistent histories interpretation.[47] These interpretations often describe reality as indeterministic by describing objects themselves as existing in states of *superposition*. A particle is in some sense distributed across multiple locations at once, before some indeterministic process of *collapse* causes the particle to settle on one location, or another, based on probabilities inherent to that superposition state. While there have been several attempts to describe what these superposition states look like, they remain difficult to intuitively understand, and seem to mix the concepts of probability and physical matter in a problematic way.[48] The notion that matter exists in a states of superposition is also quite divorced from how most people would intuitively understand indeterminism. When we think of an indeterministic world, we would generally think of a world where matter *exists*

[44]Falkenburg and Weinert (2009) summarise some historical perspectives on this issue.

[45]Which, as originally posed by Ghirardi, Rimini, and Weber, describes systems using 'a stochastic behaviour having classical features' (1985, p. 10).

[46]This is, in essence, an indeterministic version of de Broglie-Bohm theory. See E. Nelson (1966) and Bacciagaluppi (1999). I return to this theory in §5.2.2.

[47]For a summary of the consistent histories approach see Griffiths (1984).

[48]Leifer (2014) summarises the debate around this issue. See also Monton (2002), who objects to the 3N-dimensional space that these superposition states supposedly exist within.

in a certain, intuitive way, but something like the *future*, which does not exist, is what is thought of as *open* and indeterministic. The future might be *modelled* using wave functions, superpositions, and other probabilistic machinery, but existing, present things should not be understood in that way. Established indeterministic interpretations of quantum mechanics generally cannot replicate this intuition of a determinate present and an open future, since they treat a system's state at a given time as simply described by a probabilistic superposition, or not, regardless of whether that time is past, present, or future.

Nonetheless, the hard presentist could still support one of these established interpretations. This would ensure that her physics is indeterministic on a fundamental scale, but might also commit her to believing in superposition states. These interpretations yield approximate determinism on the macroscopic scale, but as I will discuss in §3.4.4, they only succeed in doing so by introducing further complications into their ontologies. So while supporting one of these views would accomplish what the hard presentist is after, I think this misses an opportunity to understand indeterminism in a more intuitive fashion. The hard presentist already draws a distinction between the existent present, and the nonexistent past and future, which may make it possible for her to posit an indeterministic world, without positing that objects *exist* in an indeterministic 'state of being'. I am therefore not satisfied to merely lean on established interpretations as a way of justifying hard presentism. The hard presentist requires an interpretation of quantum mechanics in order to make her theory workable, but there is also some indication that she may be able to *offer* something in this field, since she provides an opportunity to differentiate the probabilistic elements of a system from *ontology*. The next two subsections will introduce this idea in brief, and in chapter 5 I will explore it in more detail.

3.4.2 Toy model: pseudo-classical presentist quantum mechanics

In this subsection I will outline what a new, hard presentist theory of quantum mechanics might look like. I will initially focus on outlining the assumptions underpinning this toy model, without comparing that model to any established quantum theory or mathematics. In §3.4.3 I will analyse the physics in more detail, in order to provide some assurance that this toy model could recreate the experimental outcomes that established quantum theory predicts. In both subsections, I will focus on how the toy model describes *microscopic* systems, while questions about the macroscopic will be left until §3.4.4. As I indicated in §3.4.1, my aim is to describe the world as indeterministic, without positing that objects exist in states of superposition. Accordingly, the toy model in this section will be built on three core assumptions:

(1) There exists only a single set of classical, three-dimensional objects.

(2) Everything that exists undergoes primitive temporal passage.

(3) Passage is mathematically described by indeterministic laws of nature.

Within this model, present, time-derivative-independent properties of particles such as position and orientation have single, determinate values.[49] Properties that depend on time-derivatives such as velocity and spin are trickier to understand in a hard presentist world. As noted in §3.3.1, the presentist posits that *passage* is occuring, and therefore she accepts that particular past and future states could, *in theory*, evolve into or out of that which exists now. While there is no true answer to a question like 'where *was* the particle?', there is a true answer to 'what past position states of the particle could, in theory, precede this present state?'. (3) ensures that there are several, mutually-inconsistent

[49] I discuss ontologies of this kind in further detail in §5.2.

accounts of a particle's past that are consistent with the present, and we can assume (as per §3.3.1) that the laws will provide us with a way to weight some pasts as more probable, and others as less so. The physicist can understand her theories through this lens, if she understands time-derivative-dependent properties like velocity to relate a system's current state to those past states that could, *in theory*, evolve into it, as opposed to its *true* past state. If the physicist understands time-derivative-dependent properties in this way, then she will describe a particle's velocity using a *wave function*: a set of weighted possibilities about where a particle might have come from, or might be going to, based on what exists presently. So a microscopic system is understood to be certain and classical as it exists *presently*, but all of its past and future behaviour is modelled using wave-like mathematics. As a result, particles can generally be expected to move by constantly changing directions at random, though some directions are more probable than others.[50] Whether or not this model agrees with the predictions of quantum mechanics will depend on which courses of system evolution are more or less probable. Before I move on to that discussion, however, I will note two important points about the ontological assumptions listed above.

Firstly, I recognise that some readers may have concerns about the role of *passage* in this toy model, since passage is relied upon to do a lot of work in the theory, despite being a difficult concept to define. As emphasised in §1.3.1, this is not an issue that I will tackle in depth. Within the toy model, passage is taken to be some primitive sense in which the universe and/or every object within it *is changing*. These changes are, intuitively enough, changes in each object's position and orientation and the like, but the reader might fairly wonder what it is that these changes are occuring *with respect to*. The best answer that can

[50]This dynamics is typical of *hidden-variables* interpretations, which I discuss in chapter 5. More speculative modern theories that feature similar dynamics include those of Ellis and Goswami (2014), built around a growing-block, and Gao (2017, pp. 80), who describes classical particles undergoing random discontinuous 'jumps' even in properties such as position.

be given is a circular one: they are occuring with respect to *time*, where time is by definition a variable that observers invent to track the changes created by passage. Time does not *exist* independently of this: it is a fictional fourth dimension used by observers to understand passage, despite reality being only three-dimensional.[51] This circular definition is a consequence of passage being primitive within the toy model. Attempting to explain what passage *is*, beyond our intuitions and experiences of passage, ends up being as difficult as asking what a physical object *is* beyond our experiences of them. So it is admittedly difficult to analyse passage in any great detail, given its primitive status in the model. To some extent, the willingness of the reader to accept passage as fundamental may rest on whether that reader shares the intuition that passage is a basic phenomenon of everyday life, as it is often claimed to be.

Secondly, it is commonly assumed that within presentism everything that exists is *simultaneous* with everything else that exists, and that time passes in a *direction*. These assumptions would make sense if one was trying to isolate a present time within four-dimensional *spacetime*. In that context the objective present is modelled as a three-dimensional *hypersurface* of simultaneous events, which moves through spacetime in a particular direction. These assumptions are not sensible, however, in the three-dimensional world of hard presentism. While one might intuitively call the set of objects that exist 'the present', or claim that those objects are 'simultaneous', claims of this kind do not differentiate some objects from others. Presentness and simultaneity are redundant concepts here: there is just a three-dimensional set of things that exist.[52] Further, since time does not exist as a variable or axis, it is not sensible to describe it as having

[51]The idea that the variable of time is unreal, but change is not, is expressed by Barbour (2009). He describes change occurring to a three-dimensional universe without the need to invoke objective durations of time: exactly what I propose within this presentist toy model.

[52]I discussed presentness in chapter 2, and I return to simultaneity in chapter 4.

a 'direction'. Where a creative eternalist imagines reality 'going backwards' in time, the hard presentist can at most imagine reality if passage happened to create the opposite changes than it usually does. Even on this 'opposites day', there is no sense in which passage is occurring forwards or backwards: passage is simply occurring. I explore the consequences of this in §5.4.3.

3.4.3 Understanding quantum systems within the toy model

The toy model could provide the hard presentist with the indeterminism that she is after, so long as she can rest assured that it agrees with the predictions of accepted quantum theory. As it turns out, agreement between the toy model and quantum mechanics can be achieved in a straightforward way, as there is already an established formalism of quantum mechanics which models the evolution of quantum systems in a sufficiently similar fashion. Within the path integral formalism,[53] the probability of a system evolving into a final state from a given initial state depends on a weighted integral sum across all the *possible paths* that could lead from the latter to the former. Within the toy model, the question of where a system might move to in the next, infinitesimal moment takes the same form as it does within the path integral formalism: we consider all paths from the present state to each possible future state, and use them to calculate how the system is likely to evolve. Specifically, the probability $p(x)$ that a system will evolve into a given state x in the *immediate* future is given by:

$$p(x) = \frac{1}{Z} \int_{\text{All paths}} \exp(\frac{iS}{\hbar}) x_0$$

Where Z is a normalisation factor, S is the classical action, and x_0 is the system's initial (present) state. In English, this calculation sums up contributions from every *possible path* by which the system could progress into state x from

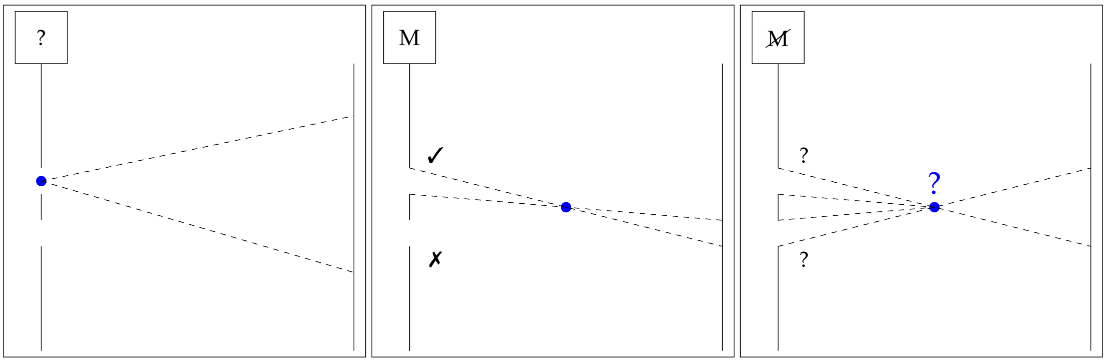
[53]Introduced by Feynman (1948). See §5.3.2 for a more detailed discussion of this formalism.

its current state x_0. Each path's contribution to the sum is determined by that path's *action*, which is in turn calculated from a non-local potential. So this toy model is an explicitly non-local one: where a particle is likely to move next is immediately determined by the entire environment that it is in, in a way that incorporates interference, uncertainty principles, and other familiar quantum mechanical effects. Overall, particles move in the manner indicated earlier: they repeatedly change direction at random. That random movement is weighted, however, in a manner consistent with established quantum theory.

This toy model is not unlike de Broglie-Bohm theory, which also describes particles as 'little balls' moving in a chaotic manner. That interpretation is generally taken to be deterministic, however, and it also draws no distinction between past, present, and future when modelling quantum systems. At all times, a system is understood by the de Broglie-Bohm theorist using a wave function, *and* a set of hidden variables describing the system's determinate state.[54] The toy model, on the other hand, represents past and future states using *only* a wave function, while the present state is represented using a determinate state and a classical potential, but no wave function.

At this stage the reader might lack an intuitive idea of how systems function within this toy model, even if they accept that the mathematics of path integrals could be carried over in some appropriate way. Systems can be understood more clearly by representing, at key points throughout an experiment, which past states could *in theory* have evolved into the present. Assuming that the laws involve conserved quantities such as momentum, we can take each 'possible past' and extend it slightly into the future, assigning to each extension a complex weighting. We can model the evolution of a system by analysing which

[54]This raises questions about whether the wave function *exists* in the form of a 'pilot wave' or 'guiding field', as proponents of the theory such as Bell (1982) believed. Dürr, Goldstein, and Zangh (1992) give a summary of this historical context. I return to this subject in chapter 5.



(a) Earlier state (b) Later, with measurement (c) Later, without measurement.

Figure 3.1: The double-slit experiment. In (a), P traverses just one slit, whether a measurement occurs or not. Later, if a measurement occurred as in (b) then P travels without interference. If no measurement occurred, as in (c), then the system is equally inclined towards possible pasts through either slit. P moves according to an interfering sum of both alternatives.

possible pasts it might evolve *in accordance with*. In general, we expect particles to move in an erratic fashion, constantly changing direction *without* conserving momentum. The most likely movements, however, will be those that conserve momentum from the directions that those particles are most likely to have come from, unless interference effects cause some paths to be suppressed.

To see how this works, consider a double-slit experiment. A particle P is incident on two slits, and then a screen. If no measurement occurs at the slits then P self-interferes on the other side, and this is detected when P hits the screen. The particle seems to traverse 'both slits at once', displaying a wave-like nature. Should a measurement occur at the slits, we find that the particle only traverses one, and also that the interference effects are removed from P's dynamics. Much debate has occurred over whether measurement 'collapses' P from a wave-like entity to a particle-like one, or whether P simply does not fit either description properly, and bears both wave- and particle-like properties.

The toy model explains this experiment in the manner depicted in Figure 3.1. P is particle-like in the present, but all of its behaviour in the past and future is modelled using wave-like mathematics. When it is incident on the slits P

merely traverses one of them, so the fact that we see this upon measurement requires no explanation or 'collapse'. Once P has moved on from the slits, its behaviour depends on whether there is a measuring device. If there *is*, then some 10^{25} other particles are arranged like *so*, which (nonlocally) affects the evolution of P. The system will strongly favour courses of behaviour consistent with P traversing one particular slit, over the other, to such a degree that all visible interference is removed, and so P progresses as if it had only traversed the one slit. If there is no measuring device, however, then no presently existing entities cause the system to favour one slit over the other. The system has 'forgotten' which slit P came through. The system proceeds according to an interfering combination of both options, since paths through either slit could, *in theory*, have evolved into the present. This evolution is mathematically described by the path integral equation, and includes interference effects, which we witness when P hits the screen. This illustrates how hard presentism could allow for a new understanding of quantum behaviour. P moves in accordance with an interfering sum of paths through both slits, not because it exists in some kind of superposition between both locations, but rather because P has an *open past*, just as it has an open future. Hard presentism is unique among theories of time, in that it models the past as *open* in exactly this fashion.

3.4.4 Macroscopic determinism and decoherence

So far, I have outlined two approaches that hard presentists could take in order to establish a fundamentally indeterministic ontology: they could adopt an established indeterministic interpretation of quantum mechanics, or they could adopt something along the lines of the toy model. Either way, hard presentists also need to establish that the macroscopic behaviour that emerges from that fundamental theory is approximately deterministic. On the scale of everyday human experience, the laws must be such that one particular course of system evolution is overwhelmingly more likely. As I discussed in §3.3.3, this would produce a world where our retrodictive practices would *converge*, producing an overarching impression that there are truths about the past.

Although it is understood a bit differently by the presentist, this problem of microscopic indeterminisim and macroscopic determinism has already seen a great deal of attention within the literature on quantum mechanics, where it is known as the *measurement problem*.[55] Already, many have questioned why the microscopic world behaves in a way that is described by probabilistic wave functions, whereas macroscopic physics is at least approximately deterministic and certain. It is exactly this problem that the hard presentist needs to solve, if they are to bridge the gap between an indeterministic fundamental physics, where there are no past truths, and an approximately deterministic macroscopic physics, where there is an *appearance* of past truths. The measurement problem is a significant problem to tackle, and is perhaps better understood as three distinct but interrelated problems. One must explain, for macroscopic systems:

(A) Why is there no *interference* between states?

(B) Why do systems appear in one state, and not in a *superposition* of many?

(C) Why do systems only appear in states of a *preferred basis*: that is, in states familiar to classical physics, rather than in mixtures of those states?[56]

For example, quantum theory might describe a particle's position as distributed between the two locations X and Y. That particle will be represented by a superposition of the states X, Y, and normalised mixed states like $(X+Y)$ and $(X-Y)$. As the particle evolves, these states will interfere with one another. In

[55] For an introduction to this problem see Zurek (1991).

[56] See Galvan (2010) for a summary of this problem.

macroscopic systems, however, we see to at least a high level of approximation that (A) there is no interference, (B) systems exist in just one state, and (C) that state could be X or Y, but never one of the mixed states. Explaining these differences is something that *every* interpretation of quantum mechanics must deal with, so possible answers to the measurement problem are not difficult for the hard presentist to find. This is, however, another area where established indeterministic interpretations of quantum mechanics run into difficulties.

Firstly, note that (A) is answered by quantum mechanical *decoherence*.[57] This is the process by which path interference is exponentially suppressed as a system expands to include larger numbers of entangled objects. While there might still be multiple states in the wave function of a system, decoherence establishes that a measured system, or any macroscopic system, will exhibit a *separation of states*. Each path in the wave function will be approximately deterministic, and will not interfere or share states with the other paths. Yet problems (B) and (C) remain: multiple paths feature in the wave function, and some consist of mixed states rather than pure ones.

Those who lean on established interpretations of quantum mechanics will find it difficult, but ultimately possible, to answer (B) and (C). Typically this is accomplished through some extra mechanism, differing for each interpretation, which involves either a real or merely apparent *collapse* of the wave function to a single, unmixed state. GRW theorists, for example, introduce spontaneous collapses of the wave function, such that each particle bears a small chance of collapsing from moment to moment. This collapse is *contagious*, in the sense that a collapsing particle will collapse other particles entangled with it. The probability of spontaneous collapse is small enough to go unwitnessed in quantum experiments, but great enough that macroscopic systems undergo collapse

[57]Introduced by Zeh (1970), who illustrates this separation of states in the EPR paradox.

almost continuously. Everettians, on the other hand, claim that there is no collapse, and all of the states of the wave function survive measurement. The *appearance* of collapse comes from observers themselves being entangled with the systems they observe, restricting them to seeing just one of the 'many worlds'. Steps (B) and (C) of the measurement problem are often where these theories bring out their most controversial or difficult claims. With that said, every interpretation of quantum mechanics does still have an answer to this problem.[58] Regardless of which you pick, they do all ultimately agree that macroscopic behaviour is approximately deterministic. So if she is willing to accept the more controversial features of one of these theories, then the hard presentist can rest easy that the macroscopic world will be approximately deterministic within her fundamentally indeterministic ontology.

The toy model from earlier could have an advantage here. Recall that the toy model describes the world as indeterministic, without positing that anything exists in a state of superposition. Instead, the toy model features a single, certain, unmixed present state: the particle is at X, not a superposition of both X and Y, and not a mixed state like $(X + Y)$. This ontology alone provides the toy model with an answer to (B) and (C), without introducing any new, controversial commitments. Recall that decoherence ensures that the wave function is separated into approximately distinct states. Because these states are non-overlapping, there will be approximately one path - one possible past, and one possible future - that could *in theory* have led to, or follow from, the certain state that *is* present. All other paths will be heavily suppressed, simply because of decoherence, combined with the fact that a single, certain present exists. This answers problem (B). One can also simply stipulate that the present exists in

[58] Of course, each answer also faces its share of criticism. For an overview see Wallace (2008).

classically 'pure' states like X, and not $(X + Y)$, solving problem (C).[59] While I will not linger on this issue any further, there is at least some reason to believe that the model proposed here, and expanded on in chapter 5, could yield an approximately deterministic macroscopic world in a straightforward way.

With that said, the toy model does not yield a fully *deterministic* evolution for measured systems: it merely yields a 'sharp peak'. Several established interpretations also retain small uncertainties on the macro-scale, including some of the theories mentioned in §3.4.1. These views are challenged by *macroscopic realists*, who argue that macroscopic entities must be entirely classical, without *any* of the uncertainty seen among the microscopic.[60] I consider much of the intuition behind this theory to stem from the discontent that physicists and philosophers alike have had with theories that describe matter as purely 'wave-like', even up to the macro-scale.[61] The toy model reconciles these concerns in a unique way. On the one hand, the only objects that exist are certain and particle-like. There exists no probabilistic, wave-like entities, on any scale, which more than satisfies the intuition underpinning macroscopic realism. On the other hand, the uncertainty inherent in the past and the future means that any experimental tests of macroscopic realism should continue to yield probabilistic results, since all experiments must operate over some finite time scale. This handily explains why ongoing tests of macroscopic realism have continued to yield probabilistic results on larger and larger scales.[62]

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[59]This mirrors how many de Broglie-Bohm theorists approach the measurement problem. See Holland (1993, ch. 8). Problems (B) and (C) vanish if the outcomes of measurements are determined by *corpuscles*, a point that I discuss further in §5.4.1.

[60]Noninvasive measurement has also traditionally been included in this definition, but this has recently been questioned: see Hermens and Maroney (2018).

[61]A more precise argument for why wave-like microscopic entities are insufficient as a foundation for macroscopic phenomena is outlined by Leggett (2002).

[62]These tests often focus on the inequalities laid out by Leggett and Garg (1985). See Emary, Lambert, and Nori (2014) for a summary of modern tests, and Zhang et al. (2018) for recent anti-realist results on the scale of classical optics experiments.

Overall, either an established interpretation or the toy model should be able to answer the hard presentist's needs. Either approach can be used to establish an ontology where on a fundamental level, there are no truths about the past or future, and reality is indeterministic; but on the scale of human experience, there is an appearance of past truth, and reality is approximately deterministic. We expect the macroscopic universe to evolve in a predictable way, with any significant probabilistic variation limited to the quantum scale.[63]

3.5. Metaphysical objections to hard presentism

At this stage, hard presentism has been outlined as a philosophical theory, and I have explored the indeterministic physical theories that could accompany it. I will leave a proper discussion of presentist quantum mechanics to chapter 5. The rest of this chapter will focus on examining metaphysical issues facing hard presentism. Importantly, this discussion of physics has established that the hard presentist does have an explanation for why people have apparent memories, and why our practices of prediction and retrodiction tend to converge around a single story of the past. This occurs because there is a narrow peak among the past and future states that could, in theory, evolve into or out of the state that the present is in, for any given macroscopic present state. Accordingly, we could expect that macroscopic agents like human beings would intuitively believe in past truths. By establishing this, the hard presentist has at least proved that past truths are not *indispensible* when explaining everyday human behaviour. The opponent of hard presentism must look to other sorts of criticisms, two of which I will examine here.

[63]It is plausible that the probabilities associated with *ancient* macroscopic events might be less convergent. While every particle might imply something about the big bang, for example, that implication might be vague enough that multiple nontrivial accounts of the big bang could, in theory, have evolved into what exists now. I return to this point in §6.2.2.

3.5.1 Objection 1: past truths are Moorean

Moore claims to know that he has hands,[64] to a greater degree of certainty than he could ever know any premise of a philosophical argument. He knows this truth simply by looking in front of himself. Of course, eyesight does not function instantaneously: light takes time to travel to the eye, and nerves take time to transmit signals to the brain. Perhaps what Moore should really be claiming is that he knows that he *had* hands, a fraction of a second ago. If this is indeed a Moorean truth, then it is an example of a *past* truth that cannot be denied. There are plenty of other examples of claims about the past that seem to be obviously and intuitively true, particularly those concerning the recent past, such as 'you read the start of this sentence'. One might be tempted to simply declare such truths as Moorean, and reject hard presentism outright. Beyond any specific truths about past events, one might be tempted to posit some Moorean truths that are more broad-reaching, for example 'there was a past' or 'things used to be different'. One might also wonder if the overarching claim 'there are truths about the past' is a Moorean truth, even if there are no specific truths about the past that are themselves Moorean. If any of these specific or generalised cases are examples of Moorean truths, then the hard presentist is in trouble.

Of course, many reject that there are Moorean truths. It can prove difficult to define what a Moorean truth even *is*, without 'T is a Moorean truth' reducing to a series of independent judgements about whether particular sceptical arguments against T are successful or not.[65] To avoid being dispensible, this talk of Moorean truths may need to invoke some stronger notion of truths that are *immune* to sceptical arguments. A common method of accomplishing

[64]The audacity! While this is his most famous example, Moore's (1925) essay focuses more heavily on other examples, particularly of *past* truths. This leads him to claim that time is *real*, in some sense, and that there must be, and we must know, at least some truths about the past.

[65]See Kelly (2005) for criticisms of this kind, and some defences.

this is to posit some special epistemic category for truths that can be known *directly*, without appealling to any reasoning or evidence that a philosophical argument might refute.[66] Introducing such a privileged epistemic category is certainly controversial. I would suggest that, even if there were past truths, they would be poor candidates for a privileged epistemic category of this kind. Our access to past truths (if they exist) comes through extrapolation from the apparent memories and evidence that we have access to in the present. Even if I am undeniably *experiencing* myself as having hands, I only *extrapolate* from that experience that I had hands a fraction of a second ago. These extrapolative practices seem to generate a fairly *indirect* sort of knowledge: they involve a kind of reasoning, not totally divorced from philosophical reasoning, and they seem to rely on grounds and evidence, just as philosophical arguments might. So it would seem odd to claim that our knowledge of the past is somehow *above* philosophical argumentation, or immune to sceptical critique.

Moore would likely believe that hard presentism could not be reconciled with human knowledge, since he maintained that humans know at least some truths about the past. I will make exactly the opposite claim: hard presentism not only avoids conflict with human knowledge, but actually aligns with it *better* than those theories that include past truths. Other theories posit a set of 'underlying truths' about the past, even though human beings never encounter any such thing. What we do encounter is information in the present, and we make judgements from that information about what the present could have evolved from. The hard presentist understands the past in exactly the same fashion. The degrees of uncertainty invoked by the hard presentist also agree well with human knowledge. Consider 'the sun rose this morning'. Though this claim

[66] White (1986) points out that Moore himself took this position, one that was then criticised by Wittgenstein (1969), who considered such belief without reasoning to be important as an *action* or *practice*, but to have little relevance to notions such as knowledge or truth.

seems obvious, we can all admit that there is a tiny chance that our knowledge on this matter is unreliable. Are you 100% sure that the sun rose this morning? Of course not: it might be more realistic to say that you are $99.99...\%$ sure. The hard presentist denies that there are any past truths, but she is happy to consider how likely, in theory, the present would be to evolve from a past where the sun rose. Her probabilistic weighting would be of a similar scale: close to certainty, but never quite there. The hard presentist only assigns significant uncertainty to micro-scale scenarios, like when comparing 'the sun rose *there* this morning' with 'the sun rose an atom's width to the left of *there* this morning'. I doubt that many people would have strong intuitions about claims on that scale, so many may be willing to accept that there is significant indeterminacy in comparisons of that kind.

Hard presentism leaves us (alethiologically) with no more or less than what we (epistemically) already have. The present implies a 99% weighting for one option, and a 1% weighting for another, with no certain *truth* beyond those weightings.[67] If one accepts that the universe only contains entities of the kind that humans could, in theory, know about, then it is reasonable to think that the universe contains no more certainty about the past than humans could, in theory, discover. So when other presentists are criticised for their abstract proxy entities and odd systems of truthmaking, and when the critics suggest that we return to the entities of regular human experience, I claim that by the very same reasoning the hard presentist can sensibly deny that there are truths about the past. We must confront the simple fact that determinate past truths are not a feature of regular human experience at all. What we experience are apparent records, memories, and the extrapolative practices we build upon them. Hard presentists can account for all of that without invoking any notion of past truth.

[67] I therefore suspect that the view's everyday implications are minor. I return to this in §6.2.3.

A final option worth considering is whether the hard presentist could accept some *indeterminate* past truths: statements that do not require a specific fact-of-the-matter about past events in order to be true. A statement about the past might be true if and only if there is no possible order of events that could lead to this present without that statement being correct: in that case, the very fact that the present is a certain way might be enough to make that statement true. Statements involving the limits of logic or the laws of physics, such as 'I was not in a different galaxy 3 seconds ago', might be made true just by the fact that I am here, now. Broad statements like 'there was a past' might be made true merely by the fact that time is passing. Many intuitive indeterminate truths don't make the cut, however. 'Things used to be different' cannot be true, so long as there is a nonzero probability associated with the past where nothing has ever changed. While this approach might preserve *some* intuitive truths, there remain familiar problems when trying to ground past truths in present reality. For example, it is unclear what these indeterminate truths are *about*, if there is no past. Even if there were a small number of indeterminate past truths that could be grounded in the present, this does little to change the hard presentist's overall position: they deny a great many intuitive past truths, whether it is all of them, or just most of them. For that reason, I maintain that there are simply no past truths. Accommodating a few indeterminate past truths does little to make this theory any more intuitive, and is probably more metaphysical trouble than it is worth.

3.5.2 Objection 2: hard presentism is too unintuitive to be acceptable

In the previous section I emphasised that hard presentism describes truth about the past as similar, in some sense, to the knowledge that human beings have concerning the past. In both cases, there is only truth or knowledge about what could, in theory, evolve into what exists now. There is no truth or knowledge that is directly *about* the past. With that said, even if hard presentism features some sort of agreement between knowledge and truth, I will stop short of trying to claim that hard presentism is *intuitive*. On the contrary, I sympathise with those who have intuitive concerns about the view, especially when intuition is often posed as a core motivation for presentism, as discussed in §1.1.2. Even if there were no knock-down arguments to prove hard presentism false, it might be the case that other theories of time are, for the most part, much more intuitive. If that were so, then it might be difficult to establish any kind of motivation for adopting hard presentism in the first place.

These competitors have intuition problems of their own, however, which are worth comparing to the problems facing hard presentism. The phenomenon of *passage*, for example, has typically been a sticking point for other temporal views.[68] Within eternalism, the perspective of a person is modelled as a *world line*: a connected series of points in spacetime. There is no sense in which you objectively 'move along' your world line from a start to a finish; nothing to describe the experience of an approaching future or a receding past. Such an experience is often regarded as a basic, intuitive everyday phenomenon,[69] and seems to be reflected in the way that we think about time, and the language we use to describe it, as I discussed in §1.1.2. The eternalist must somehow account for this experience of passage. There are two main approaches: firstly, the eternalist might claim that our experience of passage is an illusion. Some mental process gives rise to passage phenomenology, despite passage being unreal.[70] Secondly, the eternalist might claim that we do not experience passage at all, but instead we mistake our experiences for those of passage due to some form

[68]Of course, I noted in §1.3.1 that presentists also have problems with passage, but here I talk about the *phenomena*, or our experience as of temporal passage.

[69]Though claims of this kind about passage or *dynamism* have been challenged experimentally: see K. Miller (2019a), and Latham, K. Miller, and Norton (2020; 2021; forthcoming).

[70]Ismael (2016) discusses some of these theories, and puts forward one of her own.

of cognitive error.[71] In either case, the eternalist requires a theory of *psychology* to account for passage. While our supposed experience of time's passage may have roots in wider physical phenomena, ultimately the eternalist must link these phenomena to the conscious mind,[72] or in some other way establish an *illusion* or *misconception* of passage.

The literature on temporal psychology is limited by our modest grasp of psychology in general. There are, predictably, several competing theories, each of which is at best *plausible* rather than proving to be particularly *likely*.[73] It is worth comparing this issue to those raised by hard presentism. In either case, if we all intuitively *believe* in passage/past truths, then each of these theories must establish a convincing *illusion* of passage/past truths. The eternalist leans on one of several contested psychological theories to explain their illusion, while the hard presentist uses features of quantum theory such as decoherence. I leave the reader to decide whether they would prefer a theory that denies the veracity of our experience of passage, or a theory that denies the veracity of our belief in past truths. Nonetheless, I would argue that hard presentism is defensible, despite its clashes with intuition, since other theories of time also clash with our intuitions, and may encounter just as much difficulty when attempting to explain those intuitions away. I also noted in §3.4 that certain features of hard presentism, like an *open past*, could help to explain why quantum systems behave in unintuitive ways. It is plausible that an overall worldview combining hard presentism with an explanation of this kind would be no less intuitive than other temporal views, combined with other interpretations of quantum theory.

[71] See K. Miller, Holcombe, and Latham (2018) for two theories of this kind.

[72] Hartle (2005), for example, links time-asymmetric entropic processes with the perspective of a simplified 'robot' mind. His 'IGUS' model has been picked up by others as a way to understand this problem: see Ismael (2017). The level of *consciousness* needed for an observer to perceive passage will depend on the psychological theory in question.

[73] Pooley (2013) criticises a number of theories; see Ismael (2016) for a response.

3.6. Conclusion

Until now, few within the philosophy of time have seriously considered denying that there are truths about the past. Some of this reluctance might stem from the imposing task of explaining where our past-oriented beliefs come from, and why predictions based on those beliefs tend to serve us well. Hard presentism, when coupled with an appropriate understanding of physics, rejects past truths while successfully accounting for the consistent, predictable macroscopic world that we live in. With this in mind, the behaviour of the macroscopic world does not drive the hard presentist to believe in past truths. Instead, the fact that the *microscopic* universe is so chaotic and *in*consistent is exactly the evidence she needs to believe that there are no past truths at all.

Hard presentism opens up interesting new lines of thinking when it comes to interpreting quantum mechanics. One may be able to understand the indeterminacy of quantum systems in terms of the indeterminacy of the past and future, a subject that I will return to in chapter 5. When it comes to metaphysics, hard presentism bears a starkly different set of advantages and disadvantages to other forms of presentism, which could make it an attractive option for those who are sympathetic to the view, but who harbour concerns about the extra complications that often arise in the presentist's ontology or alethiology. At the very least, this view should be considered seriously alongside other theories of presentism, and indeed it may have several advantages over and above them.

Chapter 4: Presentism and Relativity

Abstract

Special and general relativity are often thought to be incompatible with temporal A-theories. In this chapter I expand on the assumptions underpinning this problem, and provide a more complete statement of it than has been provided elsewhere. I then investigate an assumption that has gone unquestioned in the literature: that, if there is an absolute *present*, there must also be absolute simultaneity among *past* things. I argue that A-theorists can deny this assumption, and instead defend a past that more closely resembles relativistic spacetime, which ultimately resolves any conflict with relativity. I also give reasons to prefer this defence over the others that A-theorists have attempted.

4.1. Introduction

Temporal A-theories posit a mind-independent, non-relative, global distinction between past, present, and future.[1] I will call this distinction *absolute*. In the ontology of an A-theory, all entities *in time* are either absolutely past, absolutely present, or absolutely future. In §1.1.1 I introduced some of the best-known versions, namely presentism (only absolutely present things exist), the growing block theory (only absolutely past and present things exist), and the moving spotlight theory (absolutely past, present, and future things exist).[2] Each of the A-theories also posits some form of robust temporal *passage*, whereby that which is present *changes* as time passes by.

[1] My definition of 'A-theory' may not match all of those elsewhere: e.g. some may not require this distinction to be global. For more on defining A-theories see C. Williams (1996). See also Fine (2005), who supports a form of realism about tense without positing an absolute present.

[2] Though it is uncommon, one could defend other combinations. Norton (2014) for example considers a *shrinking* block theory, wherein only absolutely present and future things exist.

Problematically, this absolute distinction between past, present, and future is entirely absent from some of our best theories of physics. Special relativity (SR) and general relativity (GR) are particularly thought to favour other views, or even contradict the A-theories outright. I will call this the *problem of relativity*, which I will introduce in §4.2. As one of the most serious objections facing the A-theories, this problem has already been discussed at length in the literature, but I will argue that it has previously been posed in an incomplete way. I will provide a more comprehensive version, making explicit several underlying assumptions that have been overlooked elsewhere. In particular, I will argue that there are *two* problems of relativity: one about observations of simultaneity, and another about how simultaneity exists in the world. Examining these problems will allow for me to produce a taxonomy of existing A-theoretic defences, and it will also reveal a significant new line of defence that has yet to be considered.

In §4.3 I explore this response. I argue that A-theorists should be *reductionists* about (co)presentness. Under this view, pairs of present things are by definition copresent, but there is no further primitive copresentness *relation*. This leads to a view where present things are simultaneous by definition, but there fails to emerge any larger notion of absolute simultaneity among past or future things, which ultimately accounts for the absence of such simultaneity from relativistic physics. This defence is accessible to a variety of A-theorists, provided that they can accept the particular view of (co)presentness that I defend.

4.2. The problem of relativity

In this section I expand on the problem of relativity. In §4.2.1 I raise concerns about how the problem has been posed in the literature. I then provide a more detailed version in §4.2.2, before reviewing some known responses in §4.2.3.

4.2.1 The problem in the literature

SR and GR share a lot in common, when it comes to questions about presentness and simultaneity. Both theories predict, for example, that observers can have irresolvable disagreements about which observed things were simultaneous with which. For now I will assume that the lack of absolute simultaneity in SR, and the problems it creates for A-theories, is in all relevant ways similar to the lack of absolute simultaneity in GR and the problems that issue from that. For simplicity, then, I will focus on SR. Events and the relations between them are modelled within SR using the four-dimensional manifold of Minkowski spacetime, $\mathcal{M}$. I will treat $\mathcal{M}$ as a *model* specifically connected to SR. To say that something is represented 'in' $\mathcal{M}$ is to say that it is directly relevant to relativistic physics; that the rules of SR tell us how it behaves. $\mathcal{M}$ is not to be conflated with *reality* more broadly, even if there are similarities between the two, so where appropriate I will refer to things represented in $\mathcal{M}$ as *events*, as distinct from existing *objects*.[3]

Events in $\mathcal{M}$ are assigned spatiotemporal coordinates once a reference frame has been selected. Because no one frame is singled out as *correct*, events are not taken to have *absolute* coordinates, nor to be absolutely past, present, or future. I will refer to any two events with the same temporal coordinate, for a given frame, as being *simultaneous* in that frame. When A-theorists posit an absolute present, we might expect that to imply that certain pairs of events in $\mathcal{M}$ are absolutely simultaneous, but the laws of SR dictate that judgements of simultaneity will differ between frames. Two events that are simultaneous in one frame will be temporally separated in others. There is no absolute simultaneity in $\mathcal{M}$, nor any division of $\mathcal{M}$ into absolute *times*. If $\mathcal{M}$ is, loosely speaking, an accurate depiction of reality, then this could create trouble for A-theorists.

[3] I adopt this convention for simplicity, not to take a stance on whether there exist such things as events. For more on that subject see Prior (1962) and Lowe (2013).

Of course, it goes without saying that A-theorists reject that $\mathcal{M}$ is, loosely speaking, an accurate depiction of reality. Presentists believe that reality is three-dimensional, while growing block and moving spotlight theorists posit a four-dimensional world with an *edge* or *spotlight* respectively. All A-theorists believe that some features of reality are not found in $\mathcal{M}$, and/or that some features of $\mathcal{M}$ are not found in reality. This is not, itself, controversial. There are no obvious references to ethics or aesthetics in SR, for example, but this does not imply that there are no ethical or aesthetic facts.[4] Nonetheless, it is noteworthy that all A-theorists must adopt some form of scientific *anti-realism* about $\mathcal{M}$. The A-theorist will likely accept that $\mathcal{M}$ is a useful model, which tells us *something* about reality. They will argue, however, that certain limitations on $\mathcal{M}$ prevent things like reality's edge from being explicitly represented in it. This will require careful justification: after all, simultaneity and presentness are unlike ethics and aesthetics in that we might *expect* a theory of physics like SR to tell us about them, unless some clear limitation prevents it from doing so.[5]

In parts of the literature, this anti-realism issue has been underappreciated. Classic papers on the problem of relativity often focus on features of $\mathcal{M}$, without explicitly engaging with the question of how $\mathcal{M}$ relates to reality. Perhaps the first version was tabled by Gödel (1949), who argued that SR was inconsistent with an 'objective lapse of time'. He claims that 'the assertion that [any] events A and B are simultaneous... loses its meaning' (p. 557), without distinguishing between events in the models of physics, and events (or objects) in reality. He conflates these, without justifying why this is allowable. Rietdijk (1966) argued

[4]See Zimmerman (2008). Proponents of Humean supervenience might argue that ethical/aesthetic facts supervene on mass distributions like those represented in $\mathcal{M}$, so there *are* representations of these facts too. Nonetheless, $\mathcal{M}$ might still fail in *some* way to mimic reality perfectly.

[5]Dolev argues that physics never has or *could* incorporate tense, the *now*, or the passage of time: 'it's one thing to assert that physics says nothing of passage because passage simply is not part of the language of physics... It's another thing to say that physics speaks of passage and establishes, as a matter of scientific fact, that it is not real' (2018, p. 463).

that, for similar reasons, SR is incompatible with indeterminism.[6] From the first paragraph, he launches into a discussion about events in relativistic spacetime, without addressing how to convert this into a discussion about concrete objects. So while he might prove that events in $\mathcal{M}$ are determined, in the context of that model, he does not specify the assumptions needed to conclude that *reality* is determined. The first explicit argument for the incompatibility of SR with a modern A-theory (presentism) is likely that of Putnam (1967). He asks us to 'assume Special Relativity' (p. 242), before analysing which events are 'real' for various observers in $\mathcal{M}$. Presentists would reject that observers are *in* $\mathcal{M}$ in the first place, however: they would not adopt Putnam's breed of scientific realism. While SR is troublesome for A-theorists, one must not conflate assuming SR in *some* sense with assuming that $\mathcal{M}$ is a broadly accurate picture of the world. Instead, to properly state the problem one must explicitly note the assumptions needed to connect a lack of simultaneity in $\mathcal{M}$ with a lack of an existing present.

Modern papers on the problem take this issue more seriously, though there is still an underappreciation of the diversity of anti-realisms that A-theorists could consider. This narrowness of argumentative scope can be intentional. Savitt (2000), for example, poses the problem purely in terms of the features of $\mathcal{M}$, which he conflates with features of reality. He only properly considers counter-arguments that involve redefining existence or simultaneity *within* $\mathcal{M}$. This is understandable given that the purpose of the paper is to rebut Hinchliff (1996), who suggests such a view. Yet the reader is left wondering whether many A-theorists would accept that reality mimics $\mathcal{M}$ in this way.

In other cases, this narrowness seems less intentional. Maxwell (1985) raises a similar argument to Rietdijk (1966), in this case against *probabilism*. Maxwell argues that probabilism is incompatible with SR 'interpreted realistically', but

[6]Rietdijk's definition of indeterminism differs from the modern standard: he takes an event to be determined if 'it is already "past" for some one in our "now" ' (1966, pp. 341-342).

notes that it would not conflict with 'a more modest, phenomenalistic version of special relativity' (p. 24). He does not elaborate on this, but to my mind the image is one where SR only describes observations and phenomena, without informing us about the underlying nature of time.[7] This is the opposite extreme to that of Savitt (2000), but it is still restrictive. After all, there could be many ways of being an anti-realist about $\mathcal{M}$: A-theorists might accept that SR tells us *something* about time, and that $\mathcal{M}$ bears *some* similarities with reality, rather than being naught but a predictive tool. These similarities might be of a sort, however, that are consistent with an absolute present.

More recently, Wüthrich (2013) has discussed the problem of relativity for *ersatz* presentism. As noted in §3.2, this camp posit the existence of ersatz times: sets of abstract propositions about the unreal past and future.[8] Wüthrich claims that 'SR asserts a certain structure of space and time' (p. 3). He seems to assume that, to avoid conflict with SR, presentists must accept that the set of ersatz times straightforwardly mimics $\mathcal{M}$ even if reality does not, so that presentism 'partitions $\mathcal{M}$ into past, present, and future events' (p. 2) and asserts the reality of only the present ones. Again, this fails to account for the diversity of possible responses to this problem. Even ersatz presentists might reject that the structure of ersatz times exactly mimics that of $\mathcal{M}$. They could instead argue that there are *some* similarities between them, but also some important differences.

In general, previous analyses of the problem of relativity have treated anti-realism about $\mathcal{M}$ as fringe view, but I have argued that *all* A-theorists commit to anti-realism in at least some form. We can therefore expect many A-theoretic

[7]This reading of Maxwell might be somewhat extreme, but for SR such instrumentalism is far from unheard of. Brown discusses this in depth, claiming that 'the Minkowskian metric is no more than a codification of the behaviour of clocks and rods... In general relativity, on the other hand, the $g_{\mu\nu}$ field is an autonomous dynamical player, physically significant even in the absence of the usual "matter" fields' (2005, p. 9).

[8]For more on ersatz presentism see Bourne (2006b) and Crisp (2007).

defences to invoke limits on what SR can tell us about presentness, simultaneity, and reality in general. These defences will challenge whatever assumptions are needed to conclude that, because there is no absolute simultaneity in $\mathcal{M}$, there cannot exist an absolute present. Of course, these assumptions linking reality to our best science might turn out to be quite intuitive, and so the challenges against them might be quite unintuitive. Nonetheless, it is worth recognising these assumptions explicitly when setting up the problem.

4.2.2 Stating the problem

Let us assume, for now, that the A-theorist does not wish to deny that SR is a well-confirmed theory of physics. In some basic sense, she *accepts* or *assumes* SR, but what is it *exactly* that such an A-theorist must commit to? Because SR is confirmed by observations, it seems that she must at least accept that SR gives a good account of our observations in the context of physics experiments. It will pay to examine what a 'good account' means here. After all, SR does not account for *some* aspects of our observations. Not being a theory of the mind, it does not describe what it is like to *experience* observations, to see colours or to hear sounds. More relevant to SR is (A) that we represent, on the basis of those colours and sounds, the occurrences of particular *events*, and (B) that we represent causal, dynamical, and topological properties and relations among those events. We are interested not only in the light the astronomer sees in her telescope, nor only in the supernova that she represents to have emitted that light, but also in the broader geometric system that she represents observed supernovae as situated within. To accept SR is to accept that this geometric system should be $\mathcal{M}$. Let us say that if, on the basis of observations and with our best physics in mind, we represent some entity, property, or relation X, then X is *represented through observation*. If the A-theorist accepts SR, then she accepts that absolute simultaneity relations are *not* represented through observation.

What *else* must the A-theorist accept, in light of this? This will depend on the constraints restricting what relativistic observations can tell us about reality. I will highlight a constraint here that has not seen much discussion in this context: that our observations are *backward-looking*. When making an observation we take something in the here-and-now of the observer, like light in the physicist's eyeball, and we extrapolate a representation of the *past*. This is pertinent for observations of distant things, like supernovae, but is equally true at close quarters, where we represent the very *recent* past.[9] So when a growing block theorist, for example, represents some X through observation, she represents X in the body of the block, not the edge. If she accepts SR, then she accepts that we represent *past* things, through observation, as situated in $\mathcal{M}$. This says nothing yet about *real* past events, nor *present* or *future* events, since further assumptions would be needed to conclude that those are situated in a similar way.

With that said, there is a dissonance between what we represent through observation, and how observations are *formed*. An observation of a supernova forms via a chain of 'presents': a star collapses when it is *present*, releasing light that travels when it is *present*, hitting a telescope when it is *present*, and so on. In the growing block case, observations form via a series of happenings on the *edge*, though the resultant representation is of something in the body of the block. This dissonance is usually unimportant, as we assume that properties of supernovae when they are past, like 'being white', are the same as when they are present. So we can learn about a past supernova by observing it via 'presents', without needing to interact with it when it is *past*. But there could be exceptions to this rule. As a bizarre example, consider a block universe where once objects

[9] Could we observe *ourselves*, our own mental experiences, as they are presently? This depends on what constitutes an observation: perhaps an experience itself is also an observation of that experience, or perhaps observation requires some further reflection or processing in the brain.

cease to lie on reality's edge, they become purple. The edge contains white supernovae, but the rest of the block only contains purple supernovae. Curiously, this would not be observable: what would reach our eyes via a series of presents would still be white light. While this example is a silly one, it shows that if there are features of reality whose behaviour depends on their pastness, presentness, or futurity, then there could be limits on our ability to observe them. This is unlikely to matter for properties like colour, but will matter more when discussing properties like *presentness*, or relations like *copresentness* and *simultaneity*.[10]

This is just one example of how what we represent through observation might differ from the underlying *truth* about the past things being observed. Given this, I will pose the problem of relativity as two connected problems. Firstly, would an absolute present give rise to *observations* representing absolute simultaneity among past things? This will determine whether the A-theories contradict relativistic observations outright. Secondly, would an absolute present give rise to *truths* about absolute simultaneity among past things, whether or not we observe them?[11] This will determine whether A-theorists take SR to be *missing something* about the true temporal structure of the past. This will then affect how convincing their view is: for example, if A-theorists claim that there are truths about absolute simultaneity among what we observe, but we are unable detect them, then that might be less persuasive than if A-theorists (or their rivals) could claim that there is just no absolute simultaneity to detect.

Before expanding on these problems, I will finally note that there is a debate about the relationship between (co)presentness and simultaneity. Intuitively,

[10]This issue has also been raised for *consciousness*. In response to objections by Bourne (2002) and Braddon-Mitchell (2004), Forrest (2004) argues that agents might only be conscious in the present, but not the existing past. This lack of consciousness would not be *observable*, for the reasons given above. The notion that some properties only exist presently has been explored further for the moving spotlight: see Deasy (2015) and K. Miller (2019b).

[11]This could also be posed in terms of *facts*, or the *real* past, for non-presentist A-theories.

if two things are copresent then they are simultaneous, and vice versa. There is scope for A-theorists to deny this, however, and instead claim that copresentness amounts to another relation that *is* found in $\mathcal{M}$. I will return to this in §4.2.3; for now it is enough to note that in the problems below, an extra assumption is needed to link copresentness with simultaneity. With this in mind, I will state two problems of relativity. Each is a set of mutually inconsistent claims.

Observational Problem of Relativity

(1) Multiple objects are absolutely present.

(2) If (1) then there are pairs of objects that are absolutely copresent.

(3) If (2) then we would represent, through observation, pairs of past objects as absolutely copresent.

(4) If (3) then we would represent, through observation, pairs of past objects as absolutely simultaneous.

(5) We do not represent, through observation, pairs of past objects as absolutely simultaneous.

Alethiological Problem of Relativity

(1) Multiple objects are absolutely present.

(2) If (1) then there are pairs of objects that are absolutely copresent.

(3′) If (2) then there are truths about which pairs of past objects were absolutely copresent.

(4′) If (3′) then there are truths about which pairs of past objects were absolutely simultaneous.

(5′) There are no truths about which pairs of past objects were absolutely simultaneous.

These problems are designed so that denying (1) amounts to denying the A-theories, but denying (5) or (5′) amounts to denying the veracity of SR and GR. Specifically, denying (5) means denying that SR and GR accurately describe our observations, while denying (5′) means denying that SR and GR describe the *truth* about the past things represented through those observations. Since they accept (1), A-theorists must deny at least one other premise for each problem.[12] In §4.3 I will examine (co)presentness further, but I will not attempt to deny (2): this seems highly intuitive, and perhaps even true by definition. A-theorists must therefore answer each problem differently: denying one of (3), (4), or (5), and one of (3′), (4′), or (5′). Ultimately I will advocate for denying (3) and (3′), but first I will summarise the other defences that A-theorists have attempted.

4.2.3 Responses in the literature

In this section I will examine each of (3), (4), and (5) in turn, briefly covering the responses that A-theorists have offered. I will also note along the way which of (3′), (4′), and (5′) these A-theorists would deny. I will not cover *every* response, nor discuss any particular response in detail. I seek only to summarise some well-known options, though I will consider whether each is, at first glance, likely to resolve these problems in an uncontroversial way. The fact that they do *not* will provide some motivation to explore a new defence in §4.3.

Let us begin with (3). Typically, A-theorists who deny (3) argue that absolute copresentness exists, and is equivalent to absolute simultaneity, but is also unobservable. It therefore does not enter into our best physics.[13] Proponents of this view tend not to identify anything that *makes* copresentness unobservable,

[12] Though perhaps A-theorists could be *agnostic* towards the alethiological problem, specifically. I doubt many would opt for this, since A-theorists are in the business of making claims about time, including whether there are truths about absolute simultaneity.

[13] This is not to say that our best science *never* invokes unobservable entities. Whether we should be realists about such entities is a contentious point: see Hacking (1982).

but rather they argue that there is no positive reason to think that copresentness *would* be so. Markosian, for example, suggests that SR lacks the 'philosophical baggage' (2004, pp. 31-32) to tell us whether absolute simultaneity exists: it merely shows that we do not observe it. A-theorists in this camp often accept (3′) and (4′), but reject (5′), claiming that the past is foliated into absolute *times*. This implies that there is one assessment of past events - one frame of reference, one hypothetical observer - that divides the past into slices that match the real, absolute times.[14] They are right, where other observers happen to be wrong. While our best physics does not provide any means of distinguishing a preferred frame, proponents such as Zimmerman argue that there is 'no particular reason to think that if there is a difference [between frames], it will be physics' job to discern it' (2008, p. 27). Nonetheless, such a preferred frame is certainly controversial, being decried by some as a form of 'inertial chauvinism'.[15]

Next consider (4). Intuitively, two things that are, were, or will be copresent just are two simultaneous things. Some A-theorists deny this, however, and thereby deny (4) and (4′). They argue that copresentness amounts to something else: something represented in $\mathcal{M}$, such as the light-like relation. Perhaps any event on your *past light-cone* should be considered copresent with you. This might allow for A-theorists to be scientific *realists* regarding $\mathcal{M}$, at least in the sense that $\mathcal{M}$ represents copresentness as it exists, though $\mathcal{M}$ would still lack other A-theoretical features like a growing edge. This step towards realism might be appealing, but a drawback of this approach is that it deems as copresent things that are not intuitively copresent at all. A distant supernova is light-like related to us in the moment that we see it, but given the finite speed of light we would intuitively say that the supernova did not occur *now*, but

[14]Modern views of this kind are known as *Neo-Lorentzian*, acknowledging how this mimics Lorentz's *ether* frame. See Balashov and Janssen (2003) and Craig (2008).

[15]Or, more precisely, this violates the *principle* of relativity. See Savitt (2000, pp. 569-570).

rather billions of years ago.[16] The past light-like relation is also non-transitive and non-reflexive, which is deeply unintuitive for copresentness. Proponents of these views, including Godfrey-Smith (1979) and Hinchliff (2000), question whether *intuition* should guide our judgements about how unfamiliar things like distant supernovae relate to us. Perhaps we should simply accept that the present is not as we intuitively think it to be. While denying (4) and (4′) might salvage some notion of copresentness that is consistent with relativity, it will not help *A-theorists* as I have defined them: those who posit an absolute present.[17] A-theorists, so defined, require not just a relation of copresentness among pairs of things, but a whole set of things that are present together. As per (2) we might take these to be linked: any two present things are copresent. There cannot be an *absolute* present, however, if copresentness is nontransitive or nonreflexive.[18]

Finally, consider (5). SR and GR do not invoke absolute simultaneity, but other theories of modern physics arguably do, including quantum mechanics and some theories of quantum gravity. So A-theorists might argue that our best physics either *does* feature absolute simultaneity, or is *likely to* once quantum gravity is better-understood, even if SR and GR fail to include it. This again takes a step towards scientific realism, though it is unclear why, in cases where they clash, we should be realists about quantum mechanics and not relativity theory. It is also worth noting that these other theories of physics do not explicitly include features like a growing edge, so A-theorists are still committed to anti-realism in so far as they think that physics fails to tell the 'full story' about (co)presentness. A-theorists who reject (5) would also reject (5′), claiming that there *are* truths about simultaneity among past things. This would again invoke

[16] Savitt (2000, pp. 566-569) argues that there is no reason to exclude things in your *future* light-cone from being copresent, too, which leads to even stranger examples.

[17] I will not look further into the viability of redefining copresentness for those with more modest aims: e.g. to merely define *becoming* in $\mathcal{M}$. See Stein (1991) and Clifton and Hogarth (1995).

[18] For more on 'relativised' copresentness see Wüthrich (2013) and Thyssen (2019).

a privileged frame, but this might have a better justification if physics turned out to support it. In defence of this camp, quantum mechanical wave function collapse does *seem* to invoke absolute simultaneity, with entangled particles undergoing collapse at the same global *time*.[19] Monton (2002) summarises theories of quantum gravity that lean into this idea. These views are at best speculative, so there is an understandable pushback from those such as Wüthrich (2010) who believe that they are not promising. It is hard to judge in such cases whether tomorrow's physics might contain absolute simultaneity, or not, but I am inclined against such speculation as a method of defending the A-theories anyway. It seems better to focus on whether what we know *today* lends itself to one theory of time or another, and in that light denying (5) is certainly controversial.

Some A-theorists might offer more complex defences, perhaps by denying several of the premises above. While I have not explored every option available, I hope to have shown, firstly, that the A-theorists' defences can be categorised based on which premise(s) they deny; and secondly, that there is motivation to search for new defences, since the known responses to (3), (4), and (5) are at best contentious. Two other points can be taken from this discussion. Firstly, A-theorists cannot avoid adopting some form of anti-realism about $\mathcal{M}$, so it is worth considering defences that explicitly interpret $\mathcal{M}$ as a useful model for understanding observations, rather than as a depiction of reality more broadly. Secondly, much of the controversy faced by A-theorists centres on denials of (5′). It seems hard to justify a continued insistence that there are truths about which past things were absolutely simultaneous with which, when detailed observations of those very past things has failed to yield signs of this simultaneity. If possible, it would seem better for A-theorists to take a more sympathetic stance towards our observations, and accept that past things truly are as we observe

[19] I return to this in §5.4.4. For more on the subject in relation to presentism see Esfeld (2015).

them to be. These takeaways might seem contradictory: on the one hand, we are interested in anti-realism about SR, but on the other hand, we want to take relativistic observations seriously. Both goals might be satisfied, however, by arguing that *past* things are as SR describes, but *present* things are not.

4.3. Responding with copresentness reductionism

In this section I outline a new response to the problem of relativity, centred on denying (3) and (3′). I propose that while present things are copresent by definition, there are no truths about copresentness among *past* things. We also do not represent copresentness among past things through observation. Consider, for example, two objects that are (co)present. Time passes, and those objects become past. It is now *not* true that they share a relation of copresentness. It is not true that they *are* copresent, out in the past, nor is it even true that they *were* copresent. Any copresentness between them has been entirely *lost*. When representing how these objects are situated, one might talk of their spatiotemporal coordinates relative to some frame, but it would be incorrect to describe them as being located at the same absolute time. Though this view will initially seem strange, I will argue that this is the best way for (co)presentness to be understood. This will require an analysis of what (co)presentness *is*, in §4.3.1. I then show how this resolves the problem of relativity in §4.3.2, before addressing some further implications of the view (such as those for tense logic) in §4.3.3.

4.3.1 Analysing (co)presentness

First, consider what sort of thing *presentness* is. Perhaps it is a property: moving spotlight theorists, for example, might posit a four-dimensional world containing a three-dimensional *slice* of entities, each bearing a fundamental property of presentness. The passage of time consists of one slice losing that property, as the next slice gains it. Other A-theorists might not understand presentness in this way, however. As I noted in §2.2, if there were fundamental presentness properties within presentism then everything that exists would have one. It is unclear what these properties would *do*,[20] and one could imagine a simpler presentist world that is just three-dimensional, without such properties. Recall from §2.2 that, for this reason, several thinkers have argued that presentists should take presentness to mean nothing more than existence. If something exists, then by definition it is present. Similarly, it seems needless to add to the growing block a fundamental property of presentness, bourne by everything on the edge. One could instead believe that if something lies on the edge, then by definition it is present. These views can be developed in two distinct ways. One could either maintain that presentness *exists* as a non-fundamental property,[21] or one could deny that there is presentness. Things exist (within presentism), or lie on the edge (within the growing block), and that's that. Even under this second approach, A-theorists might accept that describing reality or the edge as 'the present' is useful in practice. In what follows I will take presentness to be a real, non-fundamental property, but my arguments are compatible with either view.

What about *co*presentness? This seems to be a *relation*, but again, it is likely not fundamental. Even in the moving spotlight, where presentness properties are taken more seriously, it seems needless to claim that there is an independent, primitive relation of copresentness, relating every present thing to every other one. Rather, we might just define two things to be copresent if they are both present. This definition extends to other A-theories: for presentists, two

[20] For a more detailed discussion see Correia and Rosenkranz (2015, pp. 1-4).

[21] Tallant (2019, pp. 423–425) likens this to van Inwagen's treatment of existence: 'You can say that existence is a property if you want to. No harm in it. If existence is a property, it is the property something has if and only if it exists, if and only if there is such a thing as it... If you want to talk in that way, however, you should keep it firmly in mind that existence, so conceived, is a wholly uninteresting property' (2008, p. 37).

things are copresent if they both exist. For growing block theorists, two things are copresent if they both lie on the edge. Again, this can be developed in two ways: either we take copresentness to *exist*, but be reducible to presentness, or we take it that copresentness does not exist and that presentness is all there is to it. Again, the difference between these positions will not be too important, since even the latter camp will probably accept *talk* of copresentness, in so far as it is useful. Crucially, though, if presentness and copresentness are merely there 'by definition' then we need not be alarmed if they turn out to behave in unintuitive ways: for example, if things that seem copresent are not. After all, if that behaviour is too implausible then we could just conclude that (co)presentness must be unreal. There are just things existing, or lying on the edge.

As it happens, this view of copresentness *does* yield unintuitive behaviour. While it is simple to define copresentness among present things, we struggle to do the same for past or future things. If two objects each *are* present, then by definition they are copresent, but if two past objects each *were* present, it clearly does not follow from this alone that they *were* copresent. Otherwise, it would be true that every past thing was copresent with every other past thing! So in order for it to be true that pairs of past things were copresent, some extra piece of machinery is needed: something that was not needed for there to be, by definition, copresentness among present things. This might, for example, be *times*: two things are copresent if they are each present, but two things only *were* copresent if they were each present at the same *time*.

A similar quirk arises for *observations* of copresentness. Consider two objects which initiate causal chains of events: they emit photons, which enter detectors, and so on. An A-theorist observer would represent each object as having been present: this follows from the fact that they represent them as having existed at all. Yet, if we represent that two objects each were present, it clearly does not follow from this alone that we would represent that they were copresent. Otherwise, we would represent every past thing as copresent with every other past thing! So in order for us to represent that pairs of past things were copresent, some extra piece of information is needed: something that was not needed for there to be, by definition, copresentness among present things. This might, for example, be information about *times*: we only represent that two things *were* copresent if we represent that they were each present at the same *time*.

So while defining copresentness among present things is simple, it takes something more for there to be truths about, or observations of, copresentness among past things. There are two options available to the A-theorist from here. Firstly, she could introduce extra machinery like *times*, to allow for truths about and/or observations of absolute copresentness among past things. This brings us back to the strategies discussed in §4.2.3. Either the A-theorist would claim that we can *observe* absolute times, denying (5) and (5′), or she might argue that they are unobservable, denying (3) and (5′). Secondly, however, the A-theorist might opt *not* to introduce this machinery. Instead, she could just accept that copresentness behaves strangely. By definition pairs of present things are copresent, but there is no good definition for past or future things, so one simply does not define it to be there. Note that the behaviour of the underlying ontology is not so strange. Depending on the A-theory, present objects each have presentness, or lie on the edge, or simply exist. Later, those objects each had presentness, or laid on the edge, or existed.[22] It is only the non-fundamental relation of *copresentness* that exists among present things, but is *lost* as they transition into the past. I will call this second view *copresentness reductionism*.

In §4.3.2 I will argue that copresentness reductionism resolves the problem of relativity. Even leaving that aside, I would argue that this approach is one

[22]Though these latter claims would not be true under *hard presentism*, from chapter 3.

that A-theorists should take seriously. While it is intuitive to think that if pairs of present things *are* absolutely copresent, then there should be pairs of past things that *were* absolutely copresent, I would argue that this intuition alone is not a sufficient reason to introduce large-scale temporal structures like 'time-slices'. Copresentness reductionism, on the other hand, limits the A-theorist's ontology to only those commitments that are crucial for her view. A-theorists are by definition committed to an abolute present, not to the notion that the past or future is *sliced*. Moving spotlight theorists propose a world that is similar to the eternalist's, but with a spotlight in it. Growing block theorists also propose a world that is similar to the eternalist's, but which ends at a growing edge. Presentists propose a world that is three-dimensional, with no past or future. All of these views seem well-suited to an ontology where there is no foliation of the past or future, beyond what eternalists would believe in.[23]

While an analysis of copresentness shows how 'A and B are copresent' could be true, and yet later, 'A and B were copresent' could be untrue, I will not blame the reader if this still seems bizarre. In adopting copresentness reductionism, the A-theorist stands firm on the notion that truths require appropriate *grounds*. If all that exists that is relevant to copresentness are truths about presentness, and if those can only ground the former of the above propositions, then only the former can be true, despite how intuitively similar they might seem. This will come across as more revisionary to some A-theorists than others. As I noted in chapter 3, it is common for presentists to argue that everything that is true of the present, now, will be true of the past, later. For presentists of this ilk, the proposal that truths about copresentness are *lost* will seem concerning. Under the *hard* presentist view that I defend, however, there are no truths about the past

[23]Of course, traditional A-theories *do* feature a foliation, so this approach is still revisionary. Broad (1923, pp. 66-67) explicitly talks of 'slices' in his growing block world, while Prior (1968/2003) thought that facts about 'instants' were derivable from tensed facts, though he did regard this as 'just disguised talk about what is and has been and will be the case' (p. 124).

or future. This camp would happily accept that there are truths about present simultaneity, but no corresponding truths about past simultaneity. In general, we can expect intuitions about copresentness reductionism to vary depending on the A-theorists in question. The challenges facing this view do go further than mere intuition, however. In §4.3.3 I will examine some other concerns, but first it will pay to spell out how this view resolves the problem of relativity.

4.3.2 Responding to the problem

I will now show how copresentness reductionism allows for a new response to the problem(s) of relativity. It is worth restating the two problems from §4.2.2:

Observational Problem of Relativity

(1) Multiple objects are absolutely present.

(2) If (1) then there are pairs of objects that are absolutely copresent.

(3) If (2) then we would represent, through observation, pairs of past objects as absolutely copresent.

(4) If (3) then we would represent, through observation, pairs of past objects as absolutely simultaneous.

(5) We do not represent, through observation, pairs of past objects as absolutely simultaneous.

Alethiological Problem of Relativity

(1) Multiple objects are absolutely present.

(2) If (1) then there are pairs of objects that are absolutely copresent.

(3′) If (2) then there are truths about which pairs of past objects were absolutely copresent.

(4′) If (3′) then there are truths about which pairs of past objects were absolutely simultaneous.

(5′) There are no truths about which pairs of past objects were absolutely simultaneous.

The A-theorist who adopts copresentness reductionism will deny (3) and (3′). She believes that there is an absolute fact-of-the-matter about which objects are present, and by definition there is also an absolute fact-of-the-matter about which objects *are* copresent. She denies, however, that this 'carries through' into any observations of, or truths about, which objects *were* copresent.

The exact ontology that this leads to depends on the A-theory in question. Presentists would claim that only the three-dimensional present is real. To the extent that there are *truths* about the past or future, there are at most truths about things at four-dimensional locations, relativised to particular frames of reference. While it might be true of each past thing that it, individually, was once present, there are no truths about which past things were absolutely copresent with which, nor about which absolute *times* they existed at.[24]

Growing block theorists would adopt a similar view, but instead of talking about truths, they talk about an existing past. Reality is a four-dimensional block, and there is an absolute fact-of-the-matter about which things lie on the edge of that block. Once things are no longer located on the edge, however, they become somewhat *lost* in the body of the block. Past things have locations relative to particular frames of reference, and they still bear some relations such as causal ones, but they are not organised into absolute *times*, nor do they bear relations of absolute copresentness or simultaneity with one another.

[24]Rovelli claims that 'Einstein's simultaneity is not a discovery of a fact of the matter about multiple simultaneity surfaces: it is the discovery that simultaneity has no ontological meaning beyond convention' (2019, p. 1328). This does not 'destroy' presentism, as he claims, because simultaneity can be understood to have no meaning beyond convention *within* presentism!

Moving spotlight theorists would adopt a similar view again, but with an existing future that is also 'unsliced'. For the most part, this world is just like the eternalist's: objects are distributed in four-dimensional spacetime, with no generalised notion of absolute simultaneity. Moving spotlight theorists add to this picture a single, three-dimensional set of events within the block that are absolutely present, together. As the spotlight moves down the block, the entities left behind do not bear any relations of copresentness or simultaneity with one another. Each entity was, individually, once present, but there is nothing to ground the claim that any pair of those entities was copresent.

Within any of these views, observations will be well-predicted by SR and GR. Truths about the past (within presentism) and/or the existing past (within the growing block and moving spotlight) are structured just as $\mathcal{M}$ describes, without any relations of absolute simultaneity. A physicist might, by comparing her observations of an experiment to her observations of clocks, represent pairs of past events as having been copresent *in her frame*. The only information relevant to *absolute* (co)presentess that she could access, however, is the information that each event was individually present. Representations of absolute copresentness do not follow from that, and so they do not feature in our best physics. It is worth comparing this defence to the others against (3) that were discussed in §4.2.3. Other A-theorists have refrained from positively showing *why* copresentness is unobservable, but I have done just that. Other A-theorists have also denied (5'), claiming that there is simultaneity among past things that we fail to observe, but I have understood relativistic observations in a more charitable way. SR and GR's failure to represent absolute simultaneity among observed things is in an important sense *correct*: there is genuinely no simultaneity among the past things being represented. There is also a sense in which SR and GR are incorrect: they fail to represent the copresentness that exists by definition among present things. This might not be considered a serious failure, however, given that copresentness is non-fundamental, if it exists at all. There are no independent 'invisible strings' connecting present things that SR and GR fail to identify. It is also debateable whether these theories are even in the business of representing *present* things, since everything we represent through observation is *past* by the time we observe it. So while this position is still anti-realist with respect to relativistic spacetime, I would argue that this anti-realism is not only justifiable, but *more* charitable towards relativistic observations than many other A-theoretic defences. This defence also has advantages over denying (4) or (5). There is no need to define copresentness throughout spacetime in some new form that does not resemble simultaneity. There is also no need for A-theorists to propose new theories of physics to replace SR and GR.

I believe this response to the problem of relativity has never been explicitly identified before, though on some readings it might be implicit in a few existing A-theories. There is a trend among growing block theorists, for example, to propose that once reality accretes and becomes past it resembles relativistic spacetime. Ellis and Goswami (2014) initially depict a growing block where the past consists of world-lines, without any division into slices. Later, however, they reintroduce a foliation by arguing that GR allows for it, though this foliation is unrelated to 'radar' simultaneity. Sorkin (2007) also describes a reality that *grows*, as a result of the birth of new elements in an underlying *causal set*.[25] This reality, once grown, resembles relativistic spacetime. Sorkin does not defend an absolute present: 'there is no single "now" that spreads itself over the entire process' (p. 155). Subject to causal constraints, one can choose a temporal ordering much like one chooses a reference frame or gauge, such that 'any other order of birth which is compatible with the intrinsic precedence relation $\prec$ is to

[25]Causal set theory is one of many approaches to quantum gravity: see fn. 4, §5.1.

be regarded as physically equivalent' (p. 156). It would be too bold to say that these theorists employ the same defence against relativity that I propose, but there are certainly some similarities here that are worth recognising.

4.3.3 Other implications

Relativity aside, several questions do remain to be asked of the A-theories above. For a start, proponents of these views might need to reassess *tense logic*. Within Priorian tense logic, propositions without reference to temporal location such as p = 'It rains in Paris' and q = 'It rains in Quito' are assigned truth values as they stand, and as acted upon by tense operators P ('it was the case that') and F ('it will be the case that').[26] Copresentness reductionism alters how we understand conjunctions like $(p\&q)$. Contra Prior, the truth of $(p\&q)$ does *not* imply the truth of $F(P(p\&q))$. Indeed, there seem to be no true tensed conjunctions at all, since the use of '$\&$' in nonpresent-tensed settings leans on a notion of absolute simultaneity that is missing under this view. Given that they are untrue, A-theorists could simply understand all tensed conjunctions to be *false*, but there are other alternatives that are worth briefly considering.

One option would be to adopt a three-valued temporal logic such as that of Łukasiewicz (1930/1967), which allows for propositions to be *indeterminate* rather than true or false.[27] A-theorists might take conjunctions $P(p\&q)$, for any space-like p and q, to be merely indeterminate.[28] A second option is to understand propositions about the past using spatiotemporal locations, without tense

[26]For details about this tense logic, see Prior (1969/2003).

[27]For an overview of such logics see Malinowski (2007).

[28]Łukasiewicz (1961/1967) recognised that intuitively 'we believe that what has happened cannot be undone... what once was true remains true for ever' (p. 22), but he suggests that 'facts whose effects have disappeared altogether, and which even an omniscient mind could not infer from those now occurring, belong to the realm of possibility. One cannot say about them that they took place, but only that they were *possible*' (p. 38). Under my view, facts about simultaneity and conjunctions would indeed be facts 'whose effects have disappeared'.

operators: for example p^* = (It rains in Paris at L_1), q^* = (It rains in Quito at L_2), conjunctions $(p^* \& q^*)$, and so on. These differ from truths about the present, which take the simpliciter forms p and q. A-theorists might argue that different *grounds* for present- and nonpresent-tensed truths produce different types of truth in each case.[29] Of course, the hard presentist view introduced in chapter 3 would also be revisionary for tense logic. One might need to think of tense logic as a tool for understanding *representations* of past, present, and future things, rather than for understanding things as they exist.

While there are certainly interesting debates to be had about these logics, what matters for this chapter and for denying (3′) is just that there are no *truths* about past copresentness. There are by definition true conjunctions $(p \& q)$ for *present* things, but as time passes and the referents of p and q become past, such conjunctions are removed from the realm of truth, and are relegated to the realms of falsehood, indeterminacy, nonsense, or otherwise. While I will not linger on this issue any further, I recognise that it might not be trivial to incorporate copresentness reductionism into existing A-theories and the logics used in them. This difficulty is hardly surprising, given that many have taken a foliated past to be *essential* to A-theories, and have constructed A-theories with this in mind. In arguing for copresentness reductionism, I am also arguing that A-theorists should reject that this foliation is essential to their view, and that they should adjust their views accordingly.

In addition to questions about logic, there are several ontological puzzles that A-theorists in this camp would need to consider carefully. One might wonder, for example, what *shape* the absolute present has within the A-theories above. In at least the growing block and moving spotlight theories the absolute

[29] As I discussed in §3.2, it is already commonplace for presentists who believe in past truths to argue that they are grounded differently from truths about the present. See also Edwards (2011) and Kim and Pedersen (2018) for broader discussions of alethic pluralism.

present seems to *have* a four-dimensional shape, but it would not be observable, and because the past and future are not 'sliced' there are no truths about what shape the present *had*, or *will have*. So, frustratingly, the shape of the present might be unknowable. We *can* know that the present does not include anything we observe, so every point in it must be space-like related to the others. Beyond that, the shape cannot be seen: perhaps it is smooth and planar, or perhaps it is 'jagged' due to (say) stochasticity in temporal passage.[30] It is also unclear if the shape of the present stays constant, or whether it can change. This question may not even make *sense*, since there are no truths about the shape of the present at any time other than the present.[31] While these features do seem unusual, they need not be alarming if the shape of the present is understood to be reducible to each of the individual entities lying on the edge. The present's shape might not even properly *exist* in its own right, which means that we need not be alarmed if it seems to 'behave' unusually.

Similar discussions can be had about other problems concerning presentness and simultaneity. We might ask if the A-theory has *always* been true, or how *fast* time passes, or whether the growing block *used to be smaller*. Many of these are problems for all A-theories, not just the versions introduced here.[32] While some questions might be hard to answer without a specific foliation of the past to lean on, I see no obvious reason to think that this would render such questions unanswerable. The mere truth that each past thing existed three-dimensionally (or once accreted onto the block) might be enough to establish that presentism (or the growing block) was always true, even if there are no truths about exactly

[30] As seen in the growing block theory of Ellis and Goswami (2014), for example.

[31] Assuming it can be made sense of at all, one way to at least model the shape's changes could be to use Wheeler's framework of *superspace*. For a summary see Misner, Thorne, and Wheeler (1973, ch. 43), who suggest that superspace provides a framework for modelling the evolution of the shape of space, even when there is '[no] way whatsoever to predict, or even give meaning to, "the determinate classical history of space evolving in time" ' (pp. 1182-1183).

[32] See for example Markosian (1993) on the second question and Tan (forthcoming) on the third.

what co-existed (or co-accreted). I will not explore such ontological puzzles in further detail here, but certainly there are interesting questions facing the theories that I have introduced, just as there continue to be questions of this kind facing the A-theories in general.

4.4. Conclusion

In this chapter I have outlined a precise formulation of the problem of relativity, and a novel solution to it. This solution leans on a reductionist understanding of (co)presentness that initially seems counterintuitive, but which can be shown to be reasonable on closer inspection. Our intuitions might perhaps be rescued by reminding ourselves of what, exactly, the A-theorist believes in: not so much a robust relation of copresentness, or even a property of presentness, but just a set of *things* that are at most (co)present by definition. To the extent that A-theorists believe in a past, that past need not feature any simultaneity relations, nor be divided into time-slices, in a way that would contradict relativistic physics.

Chapter 5: Presentism and Quantum Mechanics

Abstract

In the philosophy of time, some argue that the real present has a certain, determinate state, while the unreal past and/or future are at best described with merely a balance of probabilities. I articulated such a view in chapter 3. Meanwhile in the philosophy of quantum mechanics, some argue that real systems have certain, determinate states, even while our best physics describes those systems with merely a balance of probabilities. In this chapter I provide a rough outline of a novel hidden-variables interpretation of quantum mechanics that marries these notions. I assume *presentism*: only the present exists. I also assume that systems exist in determinate states, but their evolution is stochastic. A system's past and future are therefore modelled using probabilistic mathematical tools such as wave functions. I show that this approach yields the same experimental predictions as standard quantum theory, and I explore some reasons to prefer this approach over other hidden-variables accounts.

5.1. Introduction

Quantum mechanics and the theories of relativity paint very different pictures of reality's temporal structure. Non-relativistic quantum mechanics features an absolute temporal ordering, time direction-asymmetries,[1] and perhaps even nonlocality or absolute simultaneity.[2] In special and general relativity theory, on the other hand, there is no absolute temporal ordering, simultaneity, or time direction-asymmetry. There is already a detailed scholarship on the problems

[1]Such asymmetry seems to be a feature of measurement processes, though some argue that this might only be true under specific interpretations. See Bacciagaluppi (2006).

[2]See Bohr (1935), Bohm and Hiley (1989), and Esfeld (2015).

that these differences give rise to,[3] and on the project to unify these views within a single theory of quantum gravity.[4] While I will not weigh into these debates here, they serve as motivation to explore how time can be understood within either of quantum or relativistic physics on their own. This might, in turn, help to inform our approaches to quantum gravity further down the track.

In the literature there is also a debate about how our intuitive experience of time might be reconciled with these theories of physics.[5] A typical approach is to analyse how our intuitive everyday experiences could *emerge* from a less-intuitive fundamental temporal structure.[6] In this chapter my approach will differ. I will assume that the fundamental temporal structure has certain features drawn from everyday experience and philosophy, and then analyse how quantum theory might be understood in light of those assumptions. This will amount to a rough outline of a new hidden-variables interpretation of quantum mechanics. I characterise unusual quantum behaviour as being a consequence of the limits that temporal ontology places on how systems are able to evolve.

The assumptions that this approach is founded on are *presentism*, and the *openness* of the nonpresent.[7] We can loosely define presentism as the theory that only the present exists, though a more precise definition was outlined in chapter 2. In this context, to claim that the past and future are *open* is not to claim that either exist in some 'open state'.[8] Rather it is to reject any determinate description of what state the past was in, or what state the future will be in: both are

[3]For a summary see Smolin (2013, ch. 13).

[4]These efforts often involve positing bold new temporal structures (or a lack thereof) for reality. For example see Sorkin (2007), Dowker (2014), and Dowker et al. (2020) on causal set theory, or Barbour (2012) and Barbour, Koslowski, and Mercati (2014) on shape dynamics.

[5]There are similar discussions about how our experiences could arise from our psychology, evolutionary history, methods of representation, etc. See Callender (2008), Paul (2010), Prosser (2012), Deng (2013), Dyke and Maclaurin (2013), and Ismael (2013).

[6]See for example Hartle (2005), Dowker (2014), Ismael (2016), and Arthur (2019, ch. 5, 8).

[7]This includes an open *past*, as discussed in chapter 3. See also Markosian (1995).

[8]See Grandjean (2021) for a discussion of the various kinds of *openness*.

merely described by a distribution of probabilities. This is natural enough if one subscribes to *hard presentism*, as outlined in chapter 3, and indeed the interpretation outlined in this chapter is an extension on the toy model from §3.4. The arguments of this chapter do not assume hard presentism, however: the reader can believe in objective, determinate truths about the past if they would like to. What matters for this chapter is only that such truths, if they exist, would have no impact on physics. So when analysing the dynamics of physical systems, we model the unreal past and future based only on what can be derived from the present, in combination with indeterministic laws of nature.[9]

In §5.2 I summarise interpretations of quantum mechanics in the literature, with a focus on hidden-variables theories, and on those few theories already proposed that have incorporated presentism in some manner. I point to several shortcomings with these views, motivating an investigation of a new theory that incorporates presentism more effectively. I outline such a theory in §5.3, before briefly examining its main strengths and weaknesses in §5.4.

5.2. Interpretations in the literature

In non-relativistic quantum theory, a system is described by a complex wave function Ψ. Boundary conditions restrict the values that Ψ can take, equations of motion dictate how Ψ evolves, and measurements yield random values to within $|\Psi|^2$ while reducing Ψ to a δ-function about the measured value. One way of intepreting this is to posit that Ψ *exists*, so that micro-scale reality just *is* a wave function or collection of wave functions. Despite the odd, probabilistic nature of Ψ, we might think that its prevalence in our best science is evidence

[9] An open future alone would not do: as Einstein, Tolman, and Podolsky put it: 'quantum mechanics must involve an uncertainty in the description of past events which is analogous to the uncertainty in the prediction of future events' (1931, p. 781).

that it is real.[10] We might even think that micro-scale systems are *completely* described by Ψ, and that macro-scale systems are emergent from Ψ: so Ψ is, broadly speaking, 'all there is to it'. I will call this a *wave function ontology*.[11]

Alternatively, one might defend a more intuitive view of reality, despite quantum theory not depicting it as such. At least *some* properties might have single, determinate values, both while being observed and otherwise. We might like to imagine particles as 'little balls', or more broadly as 'local beables' (LBs),[12] moving around in space much like macro-scale objects seem to. While the reader is welcome to interpret 'LB' as 'little ball', one must bear in mind that LBs could have very different features from classical balls. Their motions might be stochastic, quantised, or discontinuous; they might lack certain intuitive properties like *thickness*, or bear certain unusual properties like strong-force *colour*. Nonetheless, we might think that micro-scale reality is not fully captured by Ψ, and instead exists in a determinate state which is at least *more* similar to the reality that we are familiar with. I will call this a *pseudo-classical ontology*.

Numerous interpretations of quantum mechanics have been defended in the literature, each depicting reality and the role of Ψ in a different way. Peruzzi and Rimini (1996) identify two main schools of thought among these views: hidden-variables theories, and reduction theories. They describe them as follows:

> In hidden-variables theories, like the de Broglie-Bohm theory and Nelson's stochastic mechanics, the evolution of Ψ is always governed by the Schrodinger equation, but, contrary to the standard formulation, Ψ does not exaust the description of the system. A new variable is added to Ψ: this (hidden) variable evolves in such a way that its value after the measurement is in correspondence with the outcome.

[10] A similar view could exist for *virtual quanta* from quantum field theory. See Valente (2011).

[11] For more on the various kinds of wave function realism, see Leifer (2014) and Chen (2019).

[12] To use the popular language of Bell (1975/2004).

> In reduction theories, like the GRW theory, the evolution of Ψ, which completely specifies the state, is changed assuming a new principle of evolution. This is essentially equivalent to the Schrodinger equation in ordinary situations but it incorporates reduction in the measurement situations: the state vector collapses stochastically in accordance with quantum mechanical probabilities.
>
> (Peruzzi and Rimini 1996, pp. 510-511)

In this chapter I will include in the hidden-variables camp those theories that posit *many* extra variables in addition to Ψ. I will also include in the reductionist camp those theories that posit a state vector 'collapse', or a process that gives rise to an *appearance* of collapse, which is deterministic rather than stochastic. This includes in particular the Everettian interpetation.

The distinguishing feature of hidden-variables theories is that they reject a wave function ontology. Ψ is not enough: there is more to be said about a system's state, even if traditional quantum mechanics does not tell us as much. The hidden-variables theorist generally defends a pseudo-classical ontology, along with some deeper mechanics governing the evolution of pseudo-classical entities. Either that deeper physics is stochastic (leading to Nelsonian mechanics), or that deeper physics is deterministic (leading to de Broglie-Bohm theory). I will discuss these two variants in more detail in §5.2.1. While the hidden-variables theorist accepts that system states are *constrained* to the distribution $|\Psi|^2$, and that the Schrodinger equation dictates how that constraint evolves, they reject that Ψ is an exhaustive description of the system.

The distinguishing feature of reduction theories, on the other hand, is that they accept a wave function ontology. Either a global Ψ or multiple Ψs fully describe micro-scale systems. Macro-scale systems such as planets, people, and measuring devices are composed of micro-scale entities, and so they too are fundamentally described by Ψs. These systems are not captured by traditional quantum theory, so a 'new principle of evolution' is required to describe how Ψs behave at this scale. Perhaps the evolution of Ψ is stochastic, with random collapses to single states (leading to GRW theory).[13] Perhaps instead Ψ is deterministic, but with superpositions right up to the macro-scale (leading to the Everettian interpretation).[14] Either way, reductionists do not attempt to rework quantum mechanics to restore a pseudo-classical ontology. Instead, they ask us to re-evaluate the sorts of things that we take reality to be composed of.

Approaching quantum mechanics from a presentist perspective would likely lead to a hidden-variables theory. As I discussed in §1.1.2, presentists already support a purportedly intuitive ontology which is not 'read off' the equations of physics. Presentists motivate their view by pointing to its simplicity, or its alignment with common sense, which are exactly the motivations driving hidden-variables theorists. So the presentist would likely adopt similar priorities, and defend some form of three-dimensional pseudo-classical ontology. The presentist would argue that such a view is at worst *consistent* with quantum theory, and at best it might *explain* quantum phenomena better than other interpretations. In §5.3 and §5.4 I will introduce and defend a theory of this kind, but firstly I will motivate this position by reviewing some of the other hidden-variables theories in the literature, in §5.2.1. I will also examine in §5.2.2 the few attempts that have already been made to marry presentism with quantum mechanics. I will largely leave aside reduction theories: while I have my misgivings about Everett's 'many worlds', for example, it is not the purpose of this chapter to make any argument to that effect.

[13]See Ghirardi, Rimini, and Weber (1985) and Frigg and Hoefer (2007).

[14]Introduced by Everett (1957). For a modern discussion see Saunders et al. (2010). For defences in light of problems in quantum theory see Brown and Wallace (2005) and Sharlow (2007).

5.2.1 Hidden-variables interpretations

Hidden-variables theories have a significant historical following. Einstein was famously dissatisfied by descriptions of micro-scale reality in terms of Ψ alone,[15] but his efforts to prove the incompleteness of such descriptions faced challenges from Bell (1964/2004), among others. The original formulation of Bell's theorem was intended to show that hidden-variables theories could not be local, but there has since been some debate about whether a local hidden-variables theory could be workable if other assumptions in Bell's argument are rejected.[16] I do not wish to enter into this debate here, so I will assume that hidden-variables theories *do* need to be nonlocal, and leave the challenge of localising them to other work. Crucially that means that the exploratory presentist view in §5.3 will be nonlocal also, though localised versions of it may yet be possible.

Since Einstein, there have emerged two schools of hidden-variables theory that are worth recognising here. The first is de Broglie-Bohm theory.[17] As it was initially devised, this interpretation only commits to determinate *position* states. Other observables are either reducible to position, or they exist as probabilistic superpositions, particularly as incorporated into a quantum potential or *pilot wave*. Later adaptations allow determinate states for any, or all observables.[18] System evolution is deterministic, and involves an ongoing interaction between particles and the pilot waves that envelop them. A particle in a double-slit experiment, for example, traverses just one of the slits, but travelling with it is a wave packet that traverses both slits at once. This wave self-interferes on the other side, and passes on the effects of that interference to the motion of the particle. There is debate about the extent to which de Broglie-Bohm theorists are

[15] See for example Einstein, Podolsky, and Rosen (1935).

[16] For more on how Bell, and others, understood these assumptions see Norsen (2011).

[17] See Bohm (1952a), and also Dürr, Goldstein, and Zangh (1992) for a newer defence.

[18] See for example Vink (1993).

committed to the *existence* of this pilot wave, and how problematic that might be by comparison to the commitments of the reductionists.[19]

A second theory worth noting is Nelsonian mechanics.[20] Under this view reality is again pseudo-classical, but systems evolve according to laws featuring an indeterministic component. A particle in motion will have a deterministic 'drift' velocity, but in addition it will also *shiver* with a continuously randomised motion in all directions. Bacciagaluppi (1999, pp. 2-5) expresses the de Broglie-Bohm and Nelsonian theories in a generalised mathematics, where system evolution is governed by the guidance equation $d\mathbf{x} = \mathbf{b}dt + \sqrt{\alpha}d\boldsymbol{\omega}$. $\mathbf{b}dt$ is a deterministic component while $d\boldsymbol{\omega}$ is a stochastic Weiner process. Setting $\alpha = 1$ yields Nelsonian mechanics, while setting $\alpha = 0$ yields de Broglie-Bohm theory. $\mathbf{b}$ and $d\boldsymbol{\omega}$ depend in turn on Ψ,[21] suggesting that there remains some form of 'quantum potential' in either of these approaches. Accordingly, the two theories yield similar system dynamics. Particles (LBs) move by continuously changing directions, *careening* around the place, though they are constrained to within the Ψ distribution of traditional quantum mechanics. This summary by no means exhausts the hidden-variables theories on offer, though the ontologies posed by other theories often face more serious objections.[22]

With that said, there are several problems facing the de Broglie-Bohm and Nelsonian views too. For the most part I will leave aside these challenges until §5.4, where I discuss reasons for preferring a presentist approach. For now I will merely note two of the main concerns, to provide motivation for exploring something new. Firstly, Ψ still plays a prominent role in both of these theories,[23]

[19]For further discussion on realist de Broglie-Bohm theories see Bell (1982).

[20]For discussions of this view see E. Nelson (1966), Goldstein (1987), and Bacciagaluppi (1999).

[21]Specifically, $\mathbf{b} = \frac{\hbar}{m}\nabla S + \alpha\frac{\hbar}{2m}\frac{\nabla|\Psi|^2}{|\Psi|^2}$, while the $d\boldsymbol{\omega}$ process has $\overline{d\boldsymbol{\omega}} = 0$ and $\overline{(d\boldsymbol{\omega})^2} = \frac{\hbar}{m}$.

[22]See for example Bell (1981/2004) and J. Barrett (1996) on the 'Everett (?) theory'.

[23]Brown and Wallace argue that Ψ does all the heavy-lifting, to the extent that 'observation... is *not* discovering the position of the de Broglie–Bohm corpuscle even if it exists' (2005, p. 538).

and it may be difficult to explain that role without conceding that Ψ *exists*. This seems problematic, given that avoiding an ontology of Ψs was part of what motivated these theories in the first place. Even if we are willing to accept Ψs in the form of 'quantum potentials' alongside a more agreeable ontology of LBs, it still seems strange that there might exist a physical potential with *complex* values. Explaining how and why the Ψ field satisfies the Born rule without merely stipulating as much is also far from trivial. So there are certainly some lingering concerns about role of Ψ in these interpretations.

Secondly, I assumed earlier that these hidden-variables views are nonlocal. Not only is nonlocality 'spooky', but it also seems to invoke a notion of absolute simultaneity that the theories of relativity prohibit. It would be troublesome if these theories, while consistent with quantum mechanics, contradicted our best physics in other areas.[24] In §5.4 I will argue that presentism, while not entirely avoiding these issues, does provide the hidden-variables theorist with a *better* account of nonlocal action, which avoids contradiction with relativity theory. So presentism could prove to be a useful addition to the hidden-variables approach. Other problems will be covered in §5.4, but at this stage I hope that the reader is convinced that there is motivation to explore new, alternative hidden-variables theories. I will now consider some of the attempts that have already been made to incorporate presentism into discussions of this kind.

5.2.2 Presentism and interpretation

Little has been said on how presentism might inform our understanding of quantum mechanics. In general, physics only tends to enter into discussions of presentism when debating whether the view is contradicted by relativity.[25]

[24]For more on nonlocality see Bohm and Hiley (1988; 1989), Norsen (2011), and Esfeld (2015).
[25]A topic I covered in chapter 4, but see also Putnam (1967) and Savitt (2000).

Since the picture of time found in non-relativistic quantum mechanics does not sit easily with relativity either, we should at least be open to considering the implications of presentism in this context, even if there remain questions to be asked about whether such a view of time could carry through into theories of quantum gravity.[26] In recognition of this, perhaps, a small number of recent papers have begun to tackle this topic. Esfeld (2015) argues that presentism is at least *compatible* with quantum theory. While Esfeld stops short of investigating any *positive* role that presentism might play in this field, he does point out that presentism is accommodated particularly well by hidden-variables interpretations. As a first-order theory, the de Broglie-Bohm view depicts a world where system evolution is governed by two primitives: particle position, and wave function amplitude. Not invoked are any primitive second-order *velocities* of those things, which might otherwise have been difficult for presentists to make sense of. In §5.3 I will argue that presentism can do more than just be *compatible* with hidden-variables theories: rather, it might provide this camp with a *better* account of system evolution than those that have come before.

Secondly, Smolin and Verde (2021) introduce a view of quantum reality that they call a 'novel form of presentism' (p. 1). They posit a fundamental distinction between definite and indefinite, and an ontology of *events*, transitions from the latter to the former. There is some ambiguity about which of their claims are ontological ones: much of the paper lists what they initially call elements of *phenomenology*, but afterwards they claim to have presented the reader with an *ontology*. Some claims also seem to be mutually inconsistent, for example: 'everything that is real is so in the present moment' (p. 5), 'nothing exists or persists, things only happen' (p. 5), 'events exist for a definite duration' (p. 5), and 'indefinites flash into momentary definites, after which they are nothing.

[26] On this subject see Monton (2006) and Wüthrich (2010).

Everything we see around us exists or did just exist, but was gone in the blink of an eye' (p. 7). I have more important concerns than these issues in phrasing, however. Smolin and Verde claim that the past is definite, and the future indefinite, but it is unclear how either could be so if they are unreal. Smolin and Verde claim that 'the past... has already become definite' (p. 6) and 'being indefinite, [the future] can at any time become definite' (p. 6).[27] If the past and future are unreal then how could they *be*, or how could they *become*, in any sense at all? One might dispute whether such an account is presentist,[28] if there *is* a determinate past and an indeterminate future, which only fail to *exist* in the sense that they 'have no causal effect on us' (p. 8) or 'play no role' (p. 12).

These problems might be avoided by retreating from an ontological notion of (in)definiteness, in favour of something epistemic or phenomenological. Occasionally Smolin and Verde seem to lean this way by describing the past as 'represented in the present in records, fossils, and the like' while 'the future is the name we give to speculation as to which events will happen' (pp. 7-8). Yet there is a symmetry between these representations and speculations: neither gives a complete or *definite* picture, even those of the past. So how does one justify characterising only the past as definite? Smolin and Verde argue that quantum theory depicts the past and future differently, but this difference only extends to idealised *measurements*, not to full descriptions of real systems.[29] Take an idealised double-slit experiment, for example. Before it occurs, this experiment is described by a Ψ that seems to pass through both slits, self-interfere, and produce an indefinite measurement prediction. After it occurs the experiment is described similarly, except for a single, definite measured value. If we ask

[27]Though one could interpet their 'indefinite' future similarly to my 'open' future from §5.1, this passage in particular suggests that there is more to their ontology of the future than that.

[28]This view is unlikely to meet my own definition from chapter 2.

[29]For an early discussion of this point see Einstein, Tolman, and Podolsky (1931).

‘where was/will the particle be measured?’ then Smolin and Verde are right: the past description is definite, while the future description is not. If we ask ‘which slit(s) did/will the particle traverse?’, however, then the descriptions are equally indefinite either way. Even if we ignore questions of this kind,[30] in *practice* our measurements are limited to certain bounds of confidence, so there remains indefiniteness even in our descriptions of past measurements.

In chapter 3 I argued for a version of presentism where there are no past or future *truths*. Though this chapter was primarily focused on the metaphysics of truth, I briefly explored some applications to quantum theory in §3.4. The toy model raised there diverged from Smolin and Verde (2021) in that I embraced an indeterminate future *and past*. In the next section I will look in greater depth at what such an approach to quantum theory might look like.

5.3. Outlining a presentist interpretation

I will now explore a new presentist approach to quantum mechanics. Parts of this section may seem to ‘reinvent the wheel’ in the sense that the resultant view is similar to other hidden-variables theories from §5.2.1. While the differences are subtle, I will argue in §5.4 that they are meaningful, so it will pay to set up the view as clearly as possible. In §5.3.1 I discuss how quantum systems are initially conceptualised when approached from a presentist perspective. I then give an account of system dynamics in §5.3.2, before clarifying what it is that distinguishes this interpretation from other hidden-variables theories in §5.3.3.

5.3.1 Characterising experiments

The proposed approach to quantum theory is built on three core assumptions. Firstly, I assume presentism: only the present exists. Reality extends in three

[30] Perhaps because they are not sensible, á la the consistent histories view. See Griffiths (1984).

dimensions of space, but has no corresponding temporal extension.[31] Secondly, I assume a pseudo-classical ontology: particles are LBs with precisely-valued properties such as position and orientation, at least in the existing present. Thirdly, I assume that systems evolve in a *stochastic* or *indeterministic* way.[32] Even with perfect information about the laws of nature and the present state of a system, one could at best extrapolate a probability distribution function (PDF) representing a range of possible past and future states.

These assumptions call into question several practices used to understand systems in physics. Firstly, should we model experiments using a variable of *time*? Regardless of whether states are described by exact values, Ψs, or PDFs, physicists will generally understand a system to have a *single*, well-defined state of one of these kinds for any given value of time, without explicitly recognising which time it is *now*. A world that is presentist, pseudo-classical, and stochastic cannnot be understood in this way. Even if we were to represent systems using a time variable, there would not be a single, definitive answer to a question like 'what is the state of the system at t?'. If t were present, then a system's position state would be captured by a list of the specific locations of each particle. If t were past or future, however, then the same system at the same time t would be captured very differently: by a set of non-independent PDFs, each describing where a particle might have been, or might come to be, in so far as that can be derived from what exists presently. If t were close to the present time then these PDFs would be tightly clustered around particular locations, whereas if t were in the distant past or future then these PDFs could be very broad.

A similar problem arises for *change*. Physicists tend to understand change in an 'at-at' sense, where a system is said to change simply if its state differs

[31]This accords with the definition of presentism from chapter 2.

[32]I will not explore here the philosophical difficulties in understanding objective, fundamental stochasticity. For more on this subject see Lewis (1980), Hoefer (2007), and Myrvold (2012).

between two given times.[33] Within presentism, however, reality consists of a distribution of three-dimensional objects that move, spin, collide, and generally *change* in some immediate sense, which does not involve their being placed at multiple times. I already recognised in §1.3.1, §2.3, and §3.3 that describing this *pure* passage in rigorous detail, beyond gestures towards intuition or analogy, is an outstanding problem for presentists. It may be even harder to capture passage within a system of mathematics. In this chapter I will not seriously attempt as much. Instead, I will assume that even presentists can introduce a mathematical representation of *times*, and use that to model experiments.[34] Times are mere representations: they are useful, but limited conceptual tools for understanding how three-dimensional systems change. This system of times will also function differently from those that physicists are used to.

The crucial difference between the presentist's use of times, and those used elsewhere, is that the presentist's description of a system at a given time will differ depending on what time it is *now*. Instead of describing a system at t simpliciter, one must describe it at t from the *standpoint* of the present time t_p. If $t = t_p$ then one is describing reality as it exists now, whereas if $t \neq t_p$ then one is describing what can be represented for the system at t by drawing on present reality in combination with the laws of nature.[35] It would make sense to start by considering a time $t_p = t_1$ at the experiment's beginning. We represent possible futures with a PDF, which provides a weighted distribution of states that the system could evolve into by the 'next' time, t_2. We pick one of those options to examine, and then construct a new representation of the system *from* that state, $t_p = t_2$. The process repeats for a series of times throughout the experiment.

[33] This is a traditional view, as noted in §1.1.1. See Russell (1937, pp. 465-473).

[34] I introduced some strategies for defining 'times' in §2.3, but it would be sufficient here to define them purely in terms of the present state, plus the laws of nature.

[35] A claim of this kind would, arguably, not be properly *about* the system at t. I touched on this point when discussing truthmaking in §3.2.1, but see also Baron (2013a).

We can get an approximate understanding of systems by calculating their likely evolution at key times, and the higher the number and resolution of times that we pick, the more precise our picture of the experiment becomes.

These assumptions also call into question a second practice of physicists. Systems are often described as having properties like velocity, momentum, and spin, which are defined in terms of time-derivatives. It is unclear whether such properties could exist in a presentist world. If they did, the assumption of pseudo-classicality might require them to have determinate values, while the assumption of stochasticity might require them to have indeterminate values. Perhaps presentists should therefore maintain that properties of this kind are unreal. This is defensible: there are already other interpretations which describe quantum systems in terms of positions, or other non-time-derivative-dependent properties, alone.[36] With that said, properties like velocity and spin might be salvaged if they could be distinguished from *changes* in position or orientation. A particle's motion might be indeterministic not because its velocity is unreal, or described by a Ψ or PDF, but rather because it has a determinate velocity property that fails to completely dictate the particle's evolution. Such a velocity property would not be straightforwardly equivalent to the time-derivative of position,[37] removing any immediate need for the presentist to articulate what the time-derivative of position *means* under their view. In what follows I avoid committing to a particular view about whether such properties exist. Instead I describe dynamics for a generic property P, using the system of *times* outlined above. The state of P at t must be evaluated *from* some t_p, and only through a series of such evaluations can we build a picture of how P evolves.

[36]This is known in de Broglie-Bohm theory: see Bohm (1952b) and Bacciagaluppi (1999).

[37]Perhaps for example it could be understood as a *propensity*: see Popper (1959; 1982).

5.3.2 Dynamical theory

Let us model particles simply as sets of all of their properties. A property P of particle a at time t, as considered from a time t_p, is denoted $P_a(t, t_p)$.[38] A *system* S is modelled as the set of all properties of all particles in that system, $S(t, t_p) = \{P_a(t, t_p)\}$. By assumption all properties of a system at present $S(t_p, t_p)$ have single, determinate values. The representation of a system at nonpresent times $S(t_n, t_p)$ takes the form of a PDF, which is derived from $S(t_p, t_p)$ by a function $S(t_n, t_p) = f(S(t_p, t_p), t_n)$. The system evolves from $S(t_p, t_p)$ into a weighted random selection of one of the states in $S(t_{p+1}, t_p)$, for the 'next' time t_{p+1}. So, broadly speaking, system evolution is indeterministic, but is constrained to a PDF that is determined by the present state. Within presentism, that must be so: only the present exists, so nothing beyond the present could determine that PDF. The function f is crucial: it contains all *laws of nature* relevant to the system, and it is within the mathematics of this function that complex Ψs might enter into the theory. The features of f will determine a great deal about how the world functions. For example, if f is such that the PDF for each property $P_a(t_n, t_p)$ depends only on the properties of that *same* particle, a, then the theory will be local. If $P_a(t_n, t_p)$ is determined at least in part by properties of *other* particles, however, then the theory would be nonlocal. As noted in §5.2.1, I allow for nonlocal influences within the theory articulated here.

Recreating Nelsonian dynamics within this system would not be difficult. We could stipulate that f combines a deterministic component with a stochastic Wiener process,[39] so that the expected change in a property is given by the PDF:

$$\rho(\Delta P_a(\Delta t, t_p), \Delta t) = \frac{1}{\sqrt{4\pi\nu\Delta t}}\exp(-\frac{(\Delta P_a - \mathbf{b}\Delta t)^2}{4\nu\Delta t}), \quad \nu = \frac{\hbar}{2m} \tag{5.1}$$

[38] One could also model *relations* as properties of many particles at once, $P_{a,b,\ldots}(t, t_p)$.

[39] I would again direct the reader to E. Nelson (1966) and Bacciagaluppi (1999) for details.

Where $\mathbf{b}$ depends on a stipulated value for Ψ. This is hardly illuminating: we seek an *interpretation* of quantum behaviour, not just a mathematics describing it. Such a theory would just be Nelsonian mechanics with presentism 'tacked on', and it would likely run into the same pitfalls as those discussed in §5.2.1. Presentists can do better by drawing on certain features of the path integral formalism,[40] as was hinted at in §3.4. I will briefly summarise this formalism, before showing how it might be integrated into the presentist approach.

Feynman Path Dynamics

Within the path integral formalism, quantum systems are analysed by asking a specific sort of question. An observable P_a is measured at time t_1. For now I will denote this observable merely as $P_a(t_1)$, since the 'standpoint' time t_p is not a feature of this formalism. At a later time t_4 another measurement is made,[41] of observable $Q_b(t_4)$. In general these observables can be different, but for now I will assume that $P = Q$ and $a = b$: we measure the same property, for the same particle, twice. Now we ask the question: for a given system, and a given $P_a(t_1)$ value, what $P_a(t_4)$ values might we measure, and with what probabilities? The answer is calculated using a weighted sum of all *possible paths* from $P_a(t_1)$ to each possible $P_a(t_4)$ state. Depending on the approach taken, Ψ can feature in this formalism as a step in the mathematical process. Specifically, the value of Ψ for each $P_a(t_4)$ can be derived from the paths using the equation:

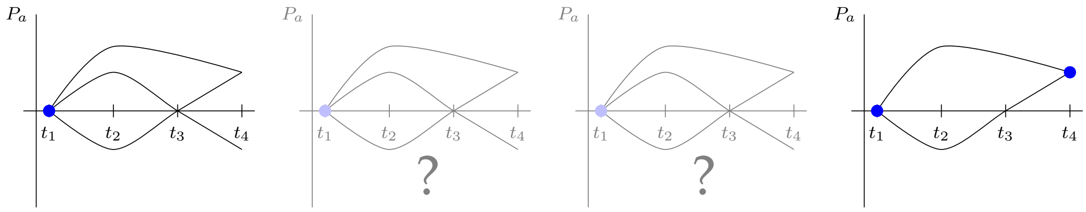
$$\Psi(P_a(t_4)) = \frac{1}{Z}\int_{\text{All paths}} \exp(\frac{iS}{\hbar})\Psi_0(P_a(t_1)) \tag{5.2}$$

[40]Introduced by Feynman (1948). I will focus on textbook theory: see for example Sakurai (1994, pp. 116-123). For more on the uses of this formalism see Khandekar and Lawande (1986).

[41]Why t_4, and not t_2? I go on to discuss other times between the two (see figures below).

Here Z is a normalisation factor, Ψ_0 is a $\delta-$function, and S is the classical *action*. The probability of measuring any given value of P_a at t_4 is given by $|\Psi(P_a(t_4))|^2$, but there are other equivalent ways of calculating these probabilities, so we need not take it that Ψ *exists*. More heavily leaned on is the action S, derived from each path's Lagrangian L, which in turn depends on the *potential* along that path. So this formalism invokes a potential field to determine which paths are more or less *probable*, though there are several differences between this potential field and the 'quantum potential' proposed by de Broglie-Bohm theorists. The former is real- rather than complex-valued, is unconstrained by the Born rule, and can take appreciable values everywhere throughout a system rather than taking the form of a 'wave packet' travelling with a specific LB. Where complex mathematics enters the theory is in the weighted integral 'sum' across possible paths. This is not a straightforward addition of probabilities: rather, one derives from the action a complex-valued amplitude for each path, and integrating across them gives rise to interference effects. In general, there will be uncertainty about what the final measurement will yield. Given a particular measured value for $P_a(t_1)$, one can construct a PDF for the final measurement by performing a separate integral sum for every possible $P_a(t_4)$ value.

A simple system S is represented in Figure 5.1. Measurements are assumed to be ideal, so the state at t_1 has an exact value. I plot separate subfigures for S as considered *from* each time t_1 through t_4: although I have not yet incorporated presentism into this picture, there is some value in representing systems in this way from the beginning. After all, before t_4 becomes present we might represent that state using a PDF, to display all of the possible values for the measurement at P_a. Once t_4 becomes present and a measurement occurs, however, we represent an exact value for $P_a(t_4)$. So there are at least some differences between these cases even before presentism comes into the picture.

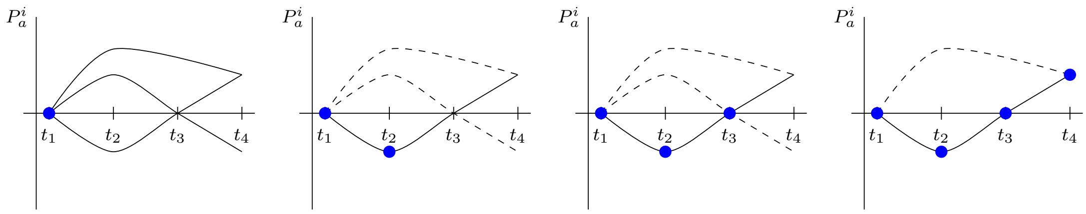


(a) t_1 = present (b) t_2 = present (c) t_3 = present (d) t_4 = present

Figure 5.1: The evolution of a system S understood using path integration. (a) depicts S after an initial measurement at t_1, when there are two possible outcomes at t_4 to consider. This formalism provides little means to assess the state when t_2 or t_3 are present, beyond a repetition of (a). (d) depicts S after a second measurement at t_4. S has a specific P_a state at t_1 and t_4, but not in between.

What can be said of S between measurements, at t_2 and t_3? One tempting answer is that there is merely a *classical uncertainty* about which path S follows. The experimenter does not know which path S is in, but its underlying state does lie in just one path. This answer runs into serious problems, however, as shown in Figure 5.2. Assuming that S has a certain state throughout t_1 to t_4 is equivalent to assuming that a *measurement* is performed on S at every point throughout its trajectory, even if the results of those measurements are not seen by any experimenter. The PDF at t_4 would then consist of a simple addition of the probability amplitudes for each possible path, without any *interference* terms. There is a simple intuition behind this idea: if there is only a classical uncertainty about which path S follows then one could not expect different paths to interfere with one another, since the underlying state of S just consists of one trajectory while the other paths are moot. This approach yields a different, and hence incorrect, calculation of likely measurement outcomes.

Traditionally, the path integral formalism would be thought to say *nothing* about S at t_2 and t_3. The formalism is only used to calculate the outcomes of measurements, and to do so it uses 'possible paths', but these are understood as mere mathematical tools rather than as literal descriptions of systems between measurements. This agnosticism does leave room for some interpretations to go



(a) t_1 = present (b) t_2 = present (c) t_3 = present (d) t_4 = present

Figure 5.2: The evolution of a system S assuming an unknown but certain state at times t_2 and t_3 between measurements. Dashed lines represent paths with a merely *classical* uncertainty. Since these will not interfere with 'genuine' paths (e.g. at t_3), even the experimenter will across multiple trials notice a change in the PDF of t_4 states. So this is *not* equivalent to Figure 5.1.

further. Everettians, for example, might describe S as properly traversing every path at once. All of them exist, and they literally interfere with one another.[42]

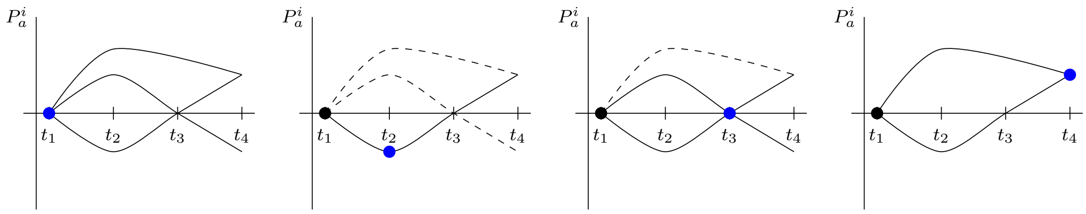
Before moving on, it will be worth noting that one can 'cut up' the calculation of the PDF at t_4 into two (or more) parts. This is done by calculating Ψ for an intermediate time like t_2, using the Ψ equation above. One can then calculate the PDF at t_4 by summing across all possible paths from t_2 to t_4, with each weighted according to both the amplitude of the path itself, and the amplitudes of $\Psi(t_2)$. One can think of this trick as splitting up the question 'what state will S be in at t_4?' into the questions 'what state will S be in at t_2?' and 'how might S then evolve from t_2 to t_4?'. Note, however, that it is neither an exact state at t_2, nor a PDF of possible states at t_2, that dictates how paths from t_2 are weighed when calculating the final PDF. Rather it is the value of Ψ that determines this, which means that there is a complex *phase* associated with each t_2 state in that calculation. This ensures that path interference at t_3 still occurs in the normal way. This will be crucial in what follows, since the same trick is used to calculate how systems evolve within a presentist interpretation. The presence of this *phase* will turn out to be a point of some intrigue for the theory.

[42]For more on Everettian approaches to path integration see Sharlow (2007). For examples of other realist approaches to possible paths see Kent (2013) and Wharton (2013).

Within a pseudo-classical presentist system, present properties $P_a(t_p, t_p)$ have determinate values whether they are being measured or not. Nonpresent properties do not exist at all, however, so one cannot describe a system S in the manner of Figures 5.2b or 5.2c, with determinate values at all of t_1, t_2, and t_3. Instead, we have to acknowledge what it is that *exists*, presently, at each time, and what possible pasts and futures can be extrapolated from that. Once the system reaches t_3, for example, there can be multiple possible paths through t_2 that factor into the calculation of its subsequent dynamics. Such a system is represented in Figure 5.3. I distinguish between the real $P_a(t_p, t_p)$ in blue, and the represented $P_a(t_n, t_p)$ in black. Figure 5.3a represents the system when t_1 is present, similar to Figure 5.1a. Both depict $P_a(t_1, t_1)$ as having an exact value, while the values of other $P_a(t_n, t_1)$ are merely represented by possible paths. Within the path integral formalism, this is thought to display the *real* value of $P_a(t_1, t_1)$, and also what the experimenter should *predict* for the measurement at t_4. The presentist understands this figure in the same way, but she also understands it to depict the system's *open future*. These trajectories are ones that the system could genuinely evolve down, given its state now.[43]

In Figure 5.3b the system has followed one such path, and has an exact value for $P_a(t_2, t_2)$. Now the possible paths of S are more limited, in part due to the existence of an idealised *measuring device*. This device is a part of the present reality from which possible paths are derived, and its state is only consistent with one specific $P_a(t_1, t_2)$. This constrains the evolution of S to just one path, while there is merely a classical uncertainty associated with other paths. One might worry, then, that this would lead to the same problems as in Figure 5.2.

[43] As this indicates, there is a close relationship between openness and modal *possibility*. I will not delve into it here, but for more on modality in Lagrangian mechanics see Butterfield (2002).



(a) t_1 = present (b) t_2 = present (c) t_3 = present (d) t_4 = present

Figure 5.3: The evolution of a presentist system S. Paths that do not pass through the definite present state (blue) have a classical uncertainty (dashed). In every diagram there is a single t_1-state that is consistent with what exists presently, in light of the measuring device. The evolution of S is constrained by this t_1-state, but no such constraint exists for unmeasured states. In (c) there are two paths that are consistent with the state at t_3, so S evolves according to an interfering sum of them. S therefore has a definite *present* state throughout its evolution, but the PDF of final t_4 states remains unchanged from Figure 5.1.

Consider however Figure 5.3c, when t_3 is present. The evolution of S from here is influenced by those things that exist, including the exact $P_a(t_3, t_3)$, and the state of the measuring device. Crucially, a property like $P_a(t_2, t_3)$ does *not* exist, nor does there exist anything else consistent with only a specific value for it. The system has 'forgotten' its state at t_2, such that multiple paths through t_2 are consistent with the state *now*. These paths are included in the integral calculation, interference and all, when determining how the system will evolve. There is still some classical uncertainty at play: paths not through $P_a(t_3, t_3)$ are not included in the calculation. These components would not interfere with the paths through $P_a(t_3, t_3)$ anyway, however, so no interference terms are lost. The expected measurement values at t_4 remain unaltered from Figure 5.1.

Finally, Figures 5.1d and 5.3d are very similar. The measurement of $P_a(t_4, t_4)$ yields an exact value, which corresponds to the real, exact value of that property at that time. There is also an exact value given for $P_a(t_1, t_4)$. In Figure 5.1d, S was understood to straightforwardly *have* that value at t_1, shown in blue. In a presentist interpretation this is not so, because properties 'at t_1' do not exist. There does exist an idealised measuring device, however, and from this we can *extrapolate* an exact $P_a(t_1, t_4)$, shown in black. What about $P_a(t_2, t_4)$ or $P_a(t_3, t_4)$? In the path integral formalism, we model S at these times using a set of possible paths, but we do not take S to *exist* as some plurality of them. Rather, we are mysteriously unable to say anything about the state of S between measurements. The presentist also denies that the past *exists* as a plurality of paths, but this is explained by the fact that the past does not exist at all. She understands these paths to depict the system's *open past*: they are trajectories that S could genuinely have evolved from, given its state now. Nothing exists that would pick out either path as the 'true' trajectory of S.

While this interpretation does describe some paths as classically uncertain, this does not erase interference effects. The fact that quantum reality is *forgetful*, particularly outside of measurement, ensures that the appropriate interference terms are retained in the presentist's dynamics, yielding the same experimental predictions as we find in standard quantum theory.[44] It is simple to generalise this to cases where measurements are of different system properties, or where they are unideal. One would merely represent the measured $P_a(t_1, t_p)$ as a *range* of values consistent with the present, rather than being specific. In either case, systems will not generally follow a smooth path, as was depicted in the simple example of Figure 5.3. Instead, we expect systems to follow the characteristic 'zigzags' of the path integral formalism. Particles (LBs) move by continuously changing directions, *careening* around the place in exactly the fashion of the de Broglie-Bohm and Nelsonian views from §5.2.1. Systems do not and cannot evolve in a *smooth* way, because they lack any retained properties or 'memories' representing a specific trajectory that they might have evolved from.

[44]This idea has arisen before in delayed-choice experiments. In Wheeler's original work he claims that 'the lesson presents itself rather as this, that the past has no existence except as it is recorded in the present' (1978, p. 41). My interpretation draws on similar thinking, though I lean less on *recordings*: when the particle lies unmeasured in the second beam-splitter, it exists, but there is no fact-of-the-matter about which path it took to get there. For more on this subject see Scully, Englert, and Walther (1991), Hiley and Callaghan (2006), and Egg (2013).

It is worth briefly reviewing the mathematics governing system evolution under this view. Earlier I noted that dynamics is captured by a function f, which dictates how systems evolve into the 'next infinitesimal moment'. A solution for f can be found by using the mathematical trick noted in §5.3.2, in the limit that a system S is 'cut up' into infinitely many sections. This would reduce the usual path integral to a series of infinitesimal integrals, each from a possible state at some t_p, to the 'next' possible state at t_{p+1}. The presentist claims that it is exactly this infinitesimal integral equation that tells us how likely a system is to evolve in any given way, based on how it exists now.[45] Crucially, the presentist does not require any additional mathematics or novel laws of nature to describe system dynamics. Generally speaking, systems are more likely to evolve down paths with a lower *action*, that run against a lower potential gradient, subject to the familiar interference effects that the path integral equations describe.

As quantum theory goes, this is mathematically very simple. So what's the catch? I noted earlier that the trick of 'cutting up' path integrals requires a *phase* for each system state at times between measurement. This ensures that path interference plays out as we observe it to. So if the path integral formula dictates system evolution under the presentist interpretation, then this phase component will need to feature somewhere. Perhaps LBs exist in the three-dimensional present, and have determinate values for all of their properties, but also have *intrinsic phases* that influence how they evolve. There are clearly questions to be asked about what these phases *are*, ontologically speaking. On the face of it they might be complex-valued properties, but they could plausibly be understood in other ways so long as any given property P_a bears some sort of a 'rotational component'. It is also plausible that phases could yet be explained away as features of the laws, or the mathematics of system evolution, rather

[45]It may be possible to reformulate the quantum least action principle to remove any references to *times*. Barbour (2009) does so, for example, but not in a *presentist* context.

than as properties of LBs *per se*. I will leave a proper exploration of this issue for further work, but it will be worth bearing this difficulty in mind as I move to consider how the presentist approach compares to other interpretations.

5.3.3 What makes the presentist interpretation unique?

The view above shares a lot in common with other hidden-variables theories. Its experimental predictions are identical, as is its description of underlying LB dynamics. Particles continuously change directions in a *Brownian* motion. This motion is either fundamentally stochastic, as in the presentist and Nelsonian theories, or deterministic but highly chaotic, as in de Broglie-Bohm theory. A presentist ontology does not clearly contradict other hidden-variables theories either, since these interpretations tend not to explicitly commit to a metaphysical position about time. So are there any clear ways in which the presentist approach differs from the other hidden-variables theories from §5.2.1?

Firstly, the presentist posits that LB evolution is influenced by a classical potential, perhaps in combination with intrinsic *phases*. This differs from other hidden-variables theories, which instead lean on *quantum* potentials closely related to Ψ. The assumption of presentism was necessary to make this shift, as otherwise a system with no quantum potential and an entire determinate *trajectory* between measurements would not undergo interference effects, as depicted in Figure 5.2. With that said, this 'classical' potential still has some unusual features. Measuring devices, in particular, have a profound impact on it. I would refer the reader back to the double-slit example in §3.4, where the measurement must somehow alter the potential of the system, or the intrinsic phase of the particle, such that it alters the PDF of possible measurement outcomes.

Secondly, the presentist explains the odd behaviour of quantum systems by leaning on *ontology* over *nomology*. On a nomological level, nothing prevents a presentist system from evolving down a single, determinate path. This would occur if there were only a single *possible* path, or if the magnitude of a single path were one while all others were zero. The reason this does not occur is that reality is limited to the present. After a particle traverses a double-slit, for example, there exists little to narrow the possibilities for where it might go next, particularly if no measurement was made. The presentist draws on this to explain the particle's stochastic motion. In other intepretations, nomology does the heavy lifting instead. The de Broglie-Bohm theorist depicts LBs as having determinate trajectories across time, nothing about which suggests that they could not follow smooth, consistent paths. It is stipulated in the *laws*, however, that the interactions between LBs and Ψ are highly chaotic, or in the Nelsonian case that they are fundamentally stochastic. These laws ensure that particles evolve in the *erratic* manner described. So even if these interpretations have identical dynamics, there are still differences in how that dynamics is *explained*.

Thirdly, adopting presentism leads to other important consequences for the ontology of hidden-variables theories, beyond the features of the dynamical theory discussed in this section. I noted in §3.4.2 that presentists can uniquely characterise time as *directionless*, and I also discussed in chapter 4 how presentism allows for an absolute present without any generalised *simultaneity*. In the next section I will explore the strengths of this presentist approach, including the strengths of these other ontological features. I will argue that even if the dynamical theory is similar, there are still reasons to think that presentism has advantages to offer over other hidden-variables theories.

5.4. Merits of the presentist approach

Now that the presentist position has been outlined, I will briefly consider how it stands up against other hidden-variables views. I will focus on the plausible advantages of presentism, though the view will also have its disadvantages, some of which I will make note of along the way. In §5.4.1 I will discuss how these views *explain* quantum systems. In §5.4.2 I will argue that presentism invokes a less-problematic field ontology. In §5.4.3 I will discuss problems of temporal (a)symmetry. Finally in §5.4.4 I will consider how presentists make sense of spatial and temporal nonlocality. These discussions will be exploratory at best: in each case I will only seek to nod towards some potential strengths of the view, leaving aside any proper discussions for further work.

5.4.1 Explanations of quantum behaviour

I noted in §5.3.3 that presentists look to ontology to explain quantum behaviour, where other hidden-variables theorists lean on nomology. This dichotomy is not totally clear-cut: the laws within presentism still explain dynamics *in part*,[46] as does ontology within other theories. I would nonetheless suggest that the presentist explanation has some unique attractions.[47] Firstly, the nomological explanations given by other hidden-variables theorists can suffer from a certain degree of inscrutability. In Nelsonian mechanics, for example, LBs are simply stipulated to evolve with a component of Brownian motion without any firm explanation or cause: the laws just say so. It is hard to say how serious a problem this is. Every interpretation has its fundamental postulates, so one might not criticise Nelson too heavily for proposing his own. Nonetheless, it is a strength of the presentist account that it can do better. Rather than proposing novel laws, the presentist draws on the familiar quantum mechanical least-action principle,

[46]The proposed view leans on a quantum-mechanical least action principle, for example. There are questions to be asked about how to interpret such principles, and what they do or do not explain. For more on this topic see Smart and Thébault (2013) and Terekhovich (2018).

[47]I will not properly explore what makes for a better explanation in general, but for more on the challenges of explaining quantum phenomena see Salmon (1984, pp. 242-259).

but the evolution this yields is constrained by the limits of a presentist world.[48] An ontological explanation of this kind 'sticks its neck out': there is a sensible debate to be had about whether presentism is a convincing ontology, a debate that presentists could in theory lose.[49] If presentists can hold their own, however, then their explanations of quantum phenomena might boast a greater level of depth than the mere assertion that the laws are as the laws are.

The presentist interpretation might also boast a clearer explanation of the link between measurement outcomes, and the determinate properties of LBs that those measurements purport to target. One criticism levied against de Broglie-Bohm theorists is that Ψ, if it exists, might fully explain measurement results on its own. If that were so, then measurements might fail to tell us anything about LBs.[50] Presentists, however, firmly deny the existence of Ψ. They instead lean on a real-valued classical potential that, while reactive to system disturbances like measurement, does not explain measurement *results* on its own. LBs genuinely determine measurement outcomes under this approach, in the manner described in §3.4.4. In general, then, there are ways in which presentists might have an explanatory edge over other hidden-variables theorists.

5.4.2 Concerns over potential structure

Marrying measurement with an underlying pseudo-classical ontology is not the only comparative advantage of a classical potential. I noted in §5.2.1 that Ψ has some curious qualities, which make it a troublesome candidate for a real, physical 'field'. For a start Ψ is complex-valued, which for example gave Schrödinger

[48]This could be what Einstein (1919/1954) famously called a *constructive* theory: it posits a fundamental ontology and argues that the phenomena arise from it. Interpretations that lean more heavily on mathematical laws might fall more to the descriptive 'principle' side, lessening their explanatory power. For a modern reflection on Einstein's views see Lange (2014).

[49]Though some have argued that the presentism/eternalism debate is misguided. I discussed this in chapter 2, but see also C. Williams (1996), Savitt (2006), and Deasy (2019a).

[50]I noted this stance of Brown and Wallace (2005) in fn. 23, §5.2.1. See also Zeh (1999).

serious reservations about regarding it as real.[51] I noted in §5.3.2 that presentists may need to make room for a *phase* component, however, so presentists might be unable to avoid the troubles of complex numbers even if they can avoid them in the *potential* they propose. Ψ faces another structural problem, however: if it exists, then it is unclear why or how it satisfies the Born rule.[52] A statistical interpretation of Ψ would allow for us to make sense of why the area beneath it always adds to one, but there is no clear reason why a physical potential should behave in this way. The de Broglie-Bohm theorist may struggle to explain why Ψ takes the form of a normalisable wave-packet around an LB, rather than being a sine wave, say, or any other non-normalisable function. The presentist's potential is untroubled by such concerns. The point where presentists need to worry about the Born rule is during the summation across all of the paths that a system could evolve down. Given the assumption of pseudo-classicality, one can stipulate that systems evolve in just one way, rather than following many paths at once. This allows for the sum across paths to trivially satisfy the Born rule without placing any further restrictions on the classical potential.

Realist views of potentials face another challenge: potentials are invariant under certain sorts of gauge transformations. The electromagnetic four-potential $A^\alpha = (\phi, \mathbf{A})$, for example, is invariant under $(\phi, \mathbf{A}) \rightarrow (\phi - \frac{\partial \psi}{\partial t}, \mathbf{A} + \nabla \psi)$ for any arbitrary differentiable function $\psi(t, \mathbf{x})$. An infinite class of different A^α functions would therefore yield the same experimental results. If A^α exists, it would be impossible for experimenters to determine which function is the *real* A^α. Bohm recognised this issue, but took it as an implication of the Aharonov-Bohm effect that a potential of this kind *must* be physical nonetheless.[53] While

[51]See Przibram et al. (1967, p. 56). For more on the history and on attempts to avoid complex number realism see Bigelow (1988, ch. 13-14), Callender (2020) and Renou et al. (2021).

[52]For more on this problem for de Broglie-Bohm theory see Callender (2007).

[53]Particles seem to interact with EM potentials in areas where $\mathbf{E}$ and $\mathbf{B}$ are zero. See Aharonov and Bohm (1959), Gerry and Singh (1979), and Aharonov, Cohen, and Rohrlich (2015).

there are other solutions to the Aharonov-Bohm effect, they also invoke odd commitments such as nonlocal field interactions, or irreducible properties of spacetime loops or *holonomies*.[54] I suspect that the presentist will be forced to bite the same bullet as Bohm, but there could be interesting links between this position and the commitment of *presentism* that are worth exploring further. While four-dimensional terms like A^α might be useful when modelling the observed past, the potential as it exists in the *present* would have to take a different form. Transformations like $\phi \to \phi - \frac{\partial \psi}{\partial t}$ do not seem to make *sense* in this three-dimensional context. So while potentials might give rise to *representations* that are gauge-invariant, what *exists* of them might not turn out to be too problematic. While this is an outstanding issue for presentists, it is not obvious that they will fare any *worse* on this front than other hidden-variables theorists.

5.4.3 Temporal (a)symmetry

In §3.4.2 I argued that presentists should not understand time as *directional*. As per chapter 2, presentists deny the reality of a temporal dimension, and instead understand time or *change* to exist in the form of temporal *passage*. Elsewhere presentists have often understood passage in terms of absolute truths or tensed facts about the nonpresent. This would construe passage as directional, since the underlying truths or facts would be directional too.[55] In chapter 3 I rejected such approaches to presentist truthmaking, and accordingly I reject that passage should be understood as having an intrinsic direction. Passage does not occur forwards or backwards: it just occurs.

This has important consequences for temporal (a)symmetry. The laws of Ψ-evolution are symmetric under time-reversal. Measurement, however, and

[54]For a summary see Lyre (2009), and for a defence of the latter position see Healey (2001).

[55]Directional passage is assumed for presentism, with little fanfare and for reasons of this kind, by the likes of Prior (1962), Markosian (1993), Price (2009), and Leininger (2015).

other macroscopic physical processes such as those from thermodynamics seem to be time-asymmetric. Ovens empty of hot gas when they are opened, but hot gas does not flow into ovens as they are closed.[56] It seems impossible for these time-asymmetric processes to arise out of a more fundamental time-symmetric physics, but if that is so then where does the time-asymmetry come from?[57] More generally, a time-symmetric physics can lead to odd results if time is treated as a dimension. E. Nelson, for example, describes an electron within a hydrogen atom as tending to move towards the nucleus 'no matter which direction we take for time' (1966, p. 1079). This makes no sense if tending towards the nucleus in one direction in time is equivalent to tending away from the nucleus in the other direction.

There are several contested solutions to these problems that I will not be covering here.[58] Usefully, however, adopting presentism allows for these issues to be completely avoided. Because time does not pass in a direction, there is some ambiguity about what 'time-reversal' could even *mean*. At best, one can compare reality to another possible world with laws that are similar to ours, but with plus signs exchanged for minus signs and vice versa. Crucially, the presentist is not committed to any particular view about what would happen in such a world: it need not be the case that everything in it evolves in the opposite fashion to how they actually do. This world is just something strange that we are speculating about, rather than being 'our world, viewed backwards'. Within non-presentist ontologies, the claims 'opening ovens empties them of hot gas, under time-reversal' and 'closing ovens does not fill them with hot gas' are contradictory, since these claims are equivalent. Within presentism,

[56]For a more detailed discussion of time-asymmetry in thermodynamics see North (2011).

[57]Time asymmetric physical processes are also discussed in relation to the time asymmetry of everyday experience. See Hartle (2005) and M. Barrett and Sober (1992).

[58]See for example Earman (2006) and North (2011).

however, these two claims are compatible, since time-reversal does not bear the same implications as it does within other views. Likewise, the presentist can accept that an electron in a hydrogen atom is attracted to the nucleus, and would still be so even if some of the signs in the laws were reversed. The same goes for other temporal asymmetries, in quantum theory or otherwise. So unlike other hidden-variables theorists, the presentist has a straightforward solution to the problems of temporal (a)symmetry.[59]

5.4.4 Spatial and temporal nonlocality

Finally, there is a long-standing debate about nonlocal physical processes within quantum mechanics. Most of these debates concern *spatial* nonlocality. If one of a pair of entangled particles is measured, for example, then something seems to happen to the other particle *instantly*.[60] Perhaps it collapses (in GRW theory), or perhaps it becomes entangled with the experimenter (in Everettian theory), or perhaps the pilot wave at its location changes (in de Broglie-Bohm theory).[61] One way or another, *something* seems to happen, and it seems to happen *simultaneously* with the act of measurement. In pseudo-classical theories this problem is particularly pronounced, since LBs would literally adjust their motions from the instant a measurement occurs. The absolute simultaneity that this seems to invoke might then contradict the theories of relativity.[62]

My arguments in chapter 4 pave the way for presentists to accommodate nonlocality without contradicting relativity. Because entangled particles each exist in the three-dimensional present, we might say that they are simultaneous. In §4.3 I argued that this simultaneity 'by definition' would not translate

[59]It has also been argued that the time-asymmetries in quantum theory are themselves evidence of A-theoretic temporal passage. See Ellis (2008).

[60]As famously posed by Einstein, Podolsky, and Rosen (1935) and replied to by Bohr (1935).

[61]For more on EPR in the de Broglie-Bohm context see Bohm and Hiley (1988).

[62]See Esfeld (2015) for a discussion of this problem in the presentist context.

into *observation*, and the existence of nonlocal quantum interactions would not undermine that argument. Such interactions are not *information-carrying*, nor do they allow for us to represent particular pairs of events as absolutely simultaneous.[63] When looking back on an EPRB experiment, for example, an observer will know from measuring one particle as spin-up that the other particle should be represented as spin-down. They will represent an entire *trajectory* for that second particle, however, without any information as to when in its flight it *becomes* spin-down. So we still fail to observe any absolute simultaneity relations. While nonlocal action would still be 'spooky', the simultaneity element in particular is not mysterious to the presentist. By contrast, other hidden-variables theorists could struggle on this point. They might, for example, assume a four-dimensional ontology that does not easily allow for simultaneity, without that amounting to a whole series of absolute 'slices'. Such a position might run more directly into conflict with relativistic physics.[64]

Alongside spatial nonlocality, there is also a growing literature on *temporal* nonlocality within quantum mechanics.[65] Could influences be transmitted from an entity at t_1 to another at t_3, without traversing t_2 along the way? On a related note, some argue that there might be retrocausality within quantum mechanics, which could either be temporally local (from t_4 to t_3) or nonlocal (from t_5 to t_3, without traversing t_4). None of this behaviour is compatible with presentism: there do not exist multiple times, so when t_3 is present there is no t_1 or t_5 for influences to be transmitted from. Since passage is nondirectional, there is also no room for backwards causation within the theory.[66] There is currently no firm evidence that temporal nonlocality or retrocausality exists, but if such evidence

[63]This is well-understood for EPR-style experiments. For more details see Blaylock (2010).

[64]There are other options, e.g. the growing block and moving spotlight views from chapter 4.

[65]See Filk (2013) and Adlam (2018).

[66]Adlam (2018, p. 4) recognises these tensions, and speculates that the historical popularity of presentism might in part explain the lack of historical support for temporal nonlocality.

were to emerge then that could put presentists in a difficult position.[67]

In the meantime, presentists may have a stonger justification for *assuming* temporal locality than is available to other hidden-variables theorists. Adlam points out that 'the combination of spatial nonlocality, temporal locality, and special relativity is straightforwardly inconsistent, since an instance of spatial nonlocality becomes an instance of temporal nonlocality under a change of reference frame' (2018, p. 5). She calls this 'the main stumbling block' of de Broglie-Bohm theory. Presentists can do better by distinguishing the present, which is *real*, from the past, which we merely *represent* through observation. The former is three-dimensional, is not modelled by relativistic reference frames, and features spatial but not temporal nonlocality. The latter is modelled as a relativistic four-dimensional manifold, without a clear distinction between spatial and temporal nonlocality. In neither regime do we apply all of the inconsistent notions above. It is also only when representing the unreal past and future that we employ what Wharton (2012) calls a *Lagrangian schema*: that is, we use a system where each path's action is assessed holistically, rather than as evolving into a final state derived from an initial one. The presentist has a convenient explanation for this: the existing *present* has a determinate state, and evolves according to evolutionary laws, but our observations of the *past* consist of representations of many states across many times. One can analyse those representations with formalisms that describe entire paths and trajectories 'as a piece', rather than being restricted to deriving later states from earlier ones. So unlike their rivals, presentists can explain why we treat *Lagrangian* systems as mere mathematical tools, while *Newtonian* systems (models of evolving states) are treated as approximate descriptions of reality, without that merely being what Adlam calls a 'prejudice in favour of temporal locality' (2018, p. 11).

[67]Some debate whether delayed choice experiments might invoke retrocausality, for example. See Egg (2013), Ellerman (2015), Chaves, Lemos, and Pienaar (2018), and Fankhauser (2019).

5.5. Conclusion

In this chapter I have introduced a novel interpretation of quantum mechanics, built around a presentist temporal ontology. By adopting presentism, one can explain quantum behaviour using familiar least-action principles, while maintaining a pseudo-classical ontology. Particles are local beables with determinate states, but their evolution is stochastic. We describe a system as having an *open* past and future, without a single determinate trajectory. This work is still exploratory: I have provided a broad outline of the view and some plausible attractions of it, but much remains to be done before this interpretation could be understood in depth. I have also not analysed whether there is a realistic prospect for this presentist treatment to find its way beyond non-relativistic quantum mechanics, into theories of quantum gravity. Nonetheless, this approach is noteworthy for its centralisation of temporal ontology when explaining quantum systems, and it shows that presentist approaches to modern physics are at least worthy of further exploration.

Chapter 6: Conclusion

In this thesis I presented four main arguments: two in defence of presentism, one in defence of A-theories more broadly, and a fourth on how presentism could be applied to the physical sciences. In chapter 2 I argued that presentism should be defined negatively, as the denial that reality is temporally extended. In chapter 3 I introduced and defended a novel approach to presentist truth-making, called *hard presentism*. Under this view, not only do the past and future not exist, but there are also no truths about them. In chapter 4 I argued that temporal A-theories can be reconciled with the theories of relativity by adopting a deflationary understanding of copresentness. While pairs of present things are by definition copresent, this does not give rise to any absolute simultaneity relations between pairs of *past* things, nor to any observations representing as much. Finally in chapter 5 I explored a new approach to interpeting quantum theory. By adopting a presentist ontology, hidden-variables theorists might be better-placed to explain the behaviour of quantum systems. It is worth stressing that chapter 5 is exploratory at best: more work would need to be done before it could be known how advantageous this approach might be.

To conclude, I will consider the view that is formed if all of these arguments are accepted together. This would be a presentist theory of time that answers the definitional issues from chapter 2, the truthmaker objection from chapter 3, and the problem of relativity from chapter 4, all while shedding new light on quantum mechanics as described in chapter 5. After outlining the core features of this position in §6.1, I will explore a few brief applications of it in §6.2. This section will serve as an opportunity to highlight a few basic consquences of the view, while also identifying some areas where further research could be valuable. I will then conclude the thesis with some final remarks in §6.3.

6.1. The Forgetful World

I will begin by assuming presentism, as it was defined in chapter 2. Reality consists of a distribution of objects in three-dimensional space. These objects might be spatially extended, but they have no corresponding temporal extension. Yet, there is temporal *passage*. Objects *change*, they *move* in three-dimensional space in some manner that does not invoke a further, fourth dimension.[1] By definition every object that exists can be described as being 'present', and all of three-dimensional reality can be referred to collectively as 'the present'. Next, in light of the arguments made in chapter 3 I will assume two intuitive alethiological principles: one of *truthmaking*, whereby all truths must supervene on being,[2] and one of *aboutness*, whereby truths can only supervene on those things that they are about.[3] These two principles, in conjunction with presentism as defined above, imply that there are only truths about the present. While that might include truths about how present things *are changing*, or about what can be *extrapolated* from the present plus the laws of nature, neither of these are properly about how things *were*, or how things *will be*. Both the past and future can be described as *open*, though that is not to say that either exists in some 'open state'. Rather, I use the term 'open' to indicate that neither the past nor future exist, nor are there any truths about them, and so at best we can represent them using a range of possibilities based on what exists presently.[4]

This view can be thought of as a 'fully committed' version of presentism. Both ontology and alethiology are 'stripped down' to the present moment. I do

[1] I return to passage below, but see also my discussions in §1.3.1 and §2.3.

[2] For details on truthmaking theory see Fine (2017) and Cameron (2018).

[3] For a discussion in context see Baron (2013a).

[4] I accept the characterisation of openness given by Markosian (1995), including his claim that an open past is justified by the same reasoning as an open future. For views challenging the conflation of openness with the notions mentioned, see Barnes and Cameron (2008).

not compromise by admitting some restricted 'pseudo-existence' for nonpresent things, as was seen in some of the theories discussed in chapter 2. Indeed, I argued that such ontologies should not be thought of as presentist at all. I also do not compromise by admitting primitively tensed *facts* or abstract *ersatz* times, as was seen in some of the theories discussed in chapter 3. This limits what we have to work with when attempting to find connections between ontology and alethiology, on the one hand, and the theories and practices found in science and everyday life, on the other. In the second half of this thesis I applied thinking of this kind to problems from the physical sciences. This began in chapter 4, where I emphasised the importance of understanding observations as representations of the past. The theories of relativity establish that we do not represent absolute simultaneity relations among past things, but this need not be a problem for the 'fully committed' presentist. If there are no truths about past things, then there are clearly no truths about which past things were copresent with which. As I argued in §4.3, even copresentness among present things should be thought of as *deflationary*. Any pair of entities in three-dimensional reality could, by definition, be said to be copresent. No harm in it.[5] This will not give rise to observations representing absolute simultaneity, however, and so one can successfully maintain that reality is three-dimensional while avoiding conflict with the theories of relativity.

By stripping from our metaphysics any understanding of past and future events beyond a probabilistic representation, the hard presentist can approach the indeterminacy of quantum systems from a new and interesting angle. I assumed in chapter 5 that *if* there are truths about the past and future, they are at least disconnected from physics, so that the evolution of physical systems can only be a function of how they are presently rather than of their full *trajectories*.

[5]To allude once more to the language of van Inwagen (2008, p. 37).

I gave no justification for this assumption: if there were truths about the past, or if there were surrogate entities like ersatz times or truthmaking properties, then there is no obvious *prima facie* reason why they must be disconnected from system evolution. Within hard presentism there is no need to worry about this problem, since there are no such truths or entities. The constraint of system evolution to bounds determined by the present state alone, and the curious and probabilistic behaviour this gives rise to, is a straightforward reflection of the fact that there *just is* a present state, and nothing more.

I regard the views outlined in chapters 2, 4, and 5 to be very natural ones for the hard presentist to adopt. I will therefore use 'hard presentism' to refer the *combination* of these theories for the rest of this chapter. So why be a hard presentist, so defined? I noted in chapter 1 that presentists often respond to objections by adding complicating extensions to their theories. When presentists are accused of lacking a definition for their view, they respond by conceding a restricted ontological status for the nonpresent, or by defining their view in terms of some further, more fundamental structure of *times*. When presentists are accused of failing to account for truths about the past, they respond by positing surrogate truthmaking properties, abstract ersatz times, or primitive tensed facts. When presentists are accused of contradicting relativity, they invent new notions of copresentness beyond 'radar' simultaneity, or they declare a particular reference frame to be undetectably *privileged*. These defences constitute new and often unusual extensions on the presentist thesis, and though the merits of each strategy differ, they can broadly be thought of as sacrificing the overall *simplicity* of presentism. These strategies are invoked in an attempt to save presentism from having unintuitive consequences, but it is unclear that they in fact succeed in preserving presentism's intuitive strength. By contrast, I have responded to these objections by stripping back presentism to its essentials. While the resultant view is perhaps not *intuitive*, it may yet prove to have other merits along the lines of parsimony. Hard presentism might not be for everyone, but its strictly limited ontology and alethiology might appeal to, as Sider puts it, 'lovers of desert landscapes' (1999, p. 325).

There are, however, some important ways in which this view is incomplete. The exploratory work on quantum theory discussed in chapter 5 is far from comprehensive. More importantly, I have often referenced a notion of presentist temporal *passage* without attempting to properly tackle how it should be understood. In §1.3.1 I explained my reasoning for sidelining passage, and indicated that passage primitivism could be a route worth exploring. It is worth noting that the arguments raised in this thesis would restrict the approaches to passage that are available to the presentist. One might intuitively define passage by leaning on a system of *times*, for example, but in chapter 2 I argued that this could be misleading, and may reduce to a definition in terms of truths and truthmaking surrogates. My rejection of this alethiology in chapter 3 implies that presentists must look elsewhere for their understanding of passage. In chapter 5 I drew on a representation of *possible paths*, constructed from what exists presently, to model the ways in which systems could change. Yet this approach also has its limits: if we accept the arguments made in chapter 4, then representations of the past built from observations in the present will also not provide us with a structure of absolute *times*, and regardless it is not obvious that passage could be defined purely in terms of the various possible pasts and futures that the present is consistent with. So the presentist still has work to do in understanding how passage is to be defined, and although I have argued that my responses to the problems of definition, truthmaking, and relativity are among the best that presentists have on offer, these responses may not make the problem of passage any easier to grapple with.

6.2. Three Brief Applications

The arguments raised in this thesis could have applications across metaphysics, the philosophy of physics, and beyond. It is not my goal to fully explore such ideas. Yet, to conclude I will briefly reflect on some of the more obvious or important applications of the hard presentist view outlined in §6.1. For the metaphysicians, I will explore in §6.2.1 the view's implications for the prospect of time travel. For the philosophers of science, I will explore in §6.2.2 the implications for how we understand observations and evidence. Finally, for everyone else, I will explore in §6.2.3 the implications for everyday belief and behaviour.

6.2.1 Time Travel

There is some debate over whether time travel is inconsistent with presentism.[6] The conspicuous lack of time-travellers arriving from the future seems to suggest that time travel is at least not *actual*: it is not something we have or ever will invent. This could be for purely circumstantial reasons: a meteorite might take us all out before our technology gets that far. Alternatively, the reasons might be more profound: perhaps time travel is *nomologically impossible*, or, prevented by the fundamental laws of physics.[7] In this chapter, however, I am interested in whether time travel could occur in a hard presentist world *purely in virtue* of it being a hard presentist world, even if the meteorite impacts or the laws of nature happened to pan out differently. At first glance, this question seems to have a simple answer: time travel is surely incompatible with presentism, for there is simply nowhere (or no-*when*) to go, other than the present.[8] This answer has

[6] For an overview of this issue see Sider (2005).

[7] One can have a similar discussion about whether time travel is *impossible* in other senses of the word. See Kment (2021) for a summary of the varieties of (im)possibility.

[8] One can find this stance articulated by Godfrey-Smith (1980) and Grey (1999, pp. 56-57).

faced some critique,[9] so I will dig into the details of this problem a little further by introducing three scenarios that at least *resemble* time travel. They will not all assume presentism, and as I will outline soon there is some controversy over whether they all constitute 'true' time travel. Each case describes the actions of a classical history enthusiast who (A) decides to time travel back to 1194 BC to see the Trojan War, and (B) finds her experiences in ancient Greece so exciting that she chooses to stay there, witnessing all she can for the rest of her life. (B) is assumed to keep the example simple: there is only one act of time travel, back to 1194 BC, which will be a clearer case study than the two acts of time travel required for a return journey.

> **Case 1: Time Machine**
>
> One day in 1194 BC a blue box appears, as if from nowhere, and Toni steps out of it. She spends many years exploring ancient Greece, before dying a fulfilled woman in 1137 BC. Three millennia pass by, and then in 1993 AD a baby is born called Toni, who grows into a classical history enthusiast. In 2016 AD, disillusioned with modern times after the election of Donald Trump, Toni dedicates herself to studying physics and builds a remarkable blue box. She steps into it, and *travels* to 1194 BC. There is a causal connection between her entering the box in 2016 AD, and her exiting it in 1194 BC. Although Toni does not exist at times from 2016 onwards, Toni does still exist *simpliciter*. She exists in the past, in 1993-2016 AD and 1194-1137 BC.

The case above is designed to depict time travel as it tends to be conceived of in popular culture.[10] Toni travels to the real 1194 BC, while leaving the real 2016 AD behind. She experiences stepping into the box in a grim Donald Trump

[9] See for example Dowe (2000) and Keller and M. Nelson (2001).

[10] For details about this form of time travel see Lewis (1976/86).

world, and then a moment later stepping out into an exciting Trojan world. **Time Machine** is clearly inconsistent with presentism: it explicitly invokes the existence of multiple times, thousands of years apart. Next, I consider two cases that might fare better in the presentist context.

Case 2: Suicide Machine

One day in 1194 BC a blue box appears, as if from nowhere, and Susie steps out of it. She spends many years exploring ancient Greece, before dying a fulfilled woman in 1137 BC. Three millennia pass by, and then in 1993 AD a baby is born called Susie, who grows into a classical history enthusiast. In 2016 AD, disillusioned with modern times after the election of Donald Trump, Susie dedicates herself to studying physics and builds a remarkable blue box. She steps into it, and vanishes. Alethically speaking, it is *true* that Susie entering the box in 2016 AD is causally connected to her exiting it in 1194 BC. It is also *true* that Susie was once exploring ancient Greece, and that she had apparent memories of 2016 while doing so. It is not the case that Susie *exists*, however. She no longer exists in the present, since she vanished; nor does she exist in the past, since the past does not exist. Susie is simply *gone*.

The case above is designed to depict presentist time travel as it is conceived of by Keller and M. Nelson (2001) and Daniels (2012). Because only the present exists, Susie cannot simply be understood as travelling to the real 1194 BC, while leaving the real 2016 AD behind. If asked in 1194-1137 BC, Susie would report having memories of stepping into the box in a grim Donald Trump world, and then a moment later stepping out into an exciting Trojan world. If asked in 2016 AD, however, Susie might not be able to anticipate being *about to* step out into a Trojan world, like she might have in **Time Machine**. Instead, stepping into the box in 2016 AD seems to simply end Susie's life. She might not find much comfort in the fact that, on some academic level, it is *true* that she was once witnessing the Trojan War. This form of so-called 'time travel' has been the subject of significant criticism,[11] but before discussing this further I will consider a third scenario that could also be consistent with presentism.

> **Case 3: Murder Machine**
>
> Maia does not exist in 1194-1137 BC, nor for three millennia afterwards. In 1993 AD a baby is born called Maia, who grows into a classical history enthusiast. In 2016 AD, disillusioned with modern times after the election of Donald Trump, Maia dedicates herself to studying physics and builds a remarkable blue box. She steps into it, and then the world outside the box is 'rewound' to exactly as it truly was in 1194 BC. The objectively present time has been changed from 2016 AD to 1194 BC. The blue box remains untouched by this process, and Maia steps out of it. She spends many years exploring ancient Greece, before dying a fulfilled woman in 1137 BC. By resetting reality, Maia has allowed for events between 1194 BC and 2016 AD to play out differently from before. It may or may not be the case that after three millennia a baby is born called Maia, who goes on to build a blue box. If this does occur, there is still no reason to believe that a second reset would play out the same as the first.

The case above is designed to depict presentist time travel as it is conceived of by Licon (2011) and Bernstein (2017).[12] Maia steps into the box, and then a grim Donald Trump world is supplanted by an exciting Trojan world. This might just involve the blue box shuffling atoms into a different arrangement. Alternatively, it might involve a full process of *rewinding* reality. Maia might look out of the window in her box and see people walking backwards, and

[11]See for example Sider (2005) and Hales (2010).

[12]A similar account of time travel within the growing block is articulated by Inwagen (2010).

clocks spinning counterclockwise, as everything between 1194 BC and 2016 AD plays out in reverse. In either case, should Maia feel guilty about the people that she expunged? Presumably she would if the present time was still 2016 AD, and Maia had merely pulled apart the universe and rearranged it.[13] It is assumed in **Murder Machine** that the box does more than this, however: it also changes the objectively present time to 1194 BC. I have remained agnostic about what this would involve, but it could be as little as changing a single *truth* about what the present time is. Perhaps this is some comfort to Maia; perhaps not.

As discussed in chapter 3, typical presentists will limit *ontology* to the present, but have a more expansive *alethiology*. These views are inconsistent with **Time Machine**, but might be consistent with **Suicide Machine** or **Murder Machine**.[14] There remains a debate over whether these cases constitute 'true' time travel,[15] but it will not be necessary for me to weigh in to that debate here, since both **Suicide Machine** and **Murder Machine** are non-starters within the specific view defended in this thesis. Both cases explicitly reference truths about the past, but under hard presentism there are no truths of this kind. Instead there are only truths about three-dimensional reality, including truths about what can be represented by extrapolating from reality using the laws of nature. In a world where Donald Trump is celebrating victory, and a young history enthusiast is building a blue box, there are no truths about the Trojans 3210 years earlier. Instead, there are only truths about the (limited) records depicting a Trojan War, and about which represented past states would be consistent with those records.

One could try to adjust **Suicide Machine** and **Murder Machine** to remove any references to nonpresent-tensed truths, but such adjustments turn out to be

[13]Licon (2011) seems to suggest a scenario of this kind, but I have assumed in constructing **Murder Machine** that presentists might want to consider avoiding this outcome.

[14]I say 'might' because there are further challenges that are not mentioned here. K. Miller (2005), for example, argues that time travellers could not appear in the present out of an *open* future.

[15]See for example Sider (2005) and Hales (2010).

seriously problematic. A hard presentist version of **Suicide Machine** would be one where Susie, upon stepping into the box, ceases to exist. The only consolation for Susie's demise is that *perhaps*, in a museum somewhere, a Greek artefact depicts a woman named Susie chilling with the Trojans. Perhaps the artefact is already this way, even as Susie enters the machine, or perhaps in the moment she ceases to exist the machine changes the artefact to include Susie. In either case, there is no reason why her vanishing would be required: doing so would not initiate any retrocausal chains of events, nor alter any truths about the past. So within hard presentism, the **Suicide Machine** becomes an overcomplicated vandalism robot that alters historical records in exchange for human sacrifice. This is surely not a case of 'true' time travel, however that is understood.

In a hard presentist version of **Murder Machine**, everything other than Maia and her box would be completely transformed: Donald Trump would cease to exist, and an exciting Trojan battle scene would replace him. This scene would *not* match what is objectively true about the world in 1194 BC, however, since there are no truths about any such thing. There is a debate over whether the Trojan War 'truly happened',[16] but under hard presentism the **Murder Machine** could not resolve this debate, since the debate would not be resolvable. At best, the world that Maia would step into would be one built from the limited records and evidence *representing* 1194 BC. The blue box might scan every atom in the universe, and then create a Trojan battle scene from it, filling in any gaps with 'best guesses'. Maia might be disatisfied, upon exiting her box and meeting an Achilles who looks suspiciously similar to Brad Pitt. It is also worth noting that, within hard presentism, the three-dimensional world is by definition 'the present'. There is no further, distinct truth about what *year* it is that a blue box could tamper with. So all the **Murder Machine** does here is rearrange the world

[16]See for example Cline (2013).

so that everyone except Maia vanishes, and some new stuff is created instead. Perhaps by *definition* that means that 2016 AD is no longer the present, but it is unlikely that this will allow Maia to avoid feeling guilty about all the people that she killed. So within hard presentism, the **Murder Machine** destroys the entire universe and replaces it with high-quality historical re-enactment theatre. While this is at least more impactful than a hard presentist **Suicide Machine**, it again does not seem like a case of 'true' time travel.

So even if one could argue that other theories of presentism allow for time travel, hard presentism clearly does not. Under this view, there is not only no temporal dimension to travel along, but there are also no truths about the nonpresent that time machines could influence, or be influenced by. The hard presentist therefore has a simpler explanation for why we do not see any time travellers: it follows from their ontology, without any need to delve deeper into (say) the laws of physics. This simpler explanation might in some ways be a better one, though I will not investigate that issue in any further detail here.

6.2.2 Scientific Practice

In chapter 5 I examined how presentism could contribute to interpretations of physics. I approach systems by first specifying how things are *now*, before modelling a distribution of possible pasts and futures. This diverges from the generally accepted practice of modelling systems as having a single, well-defined state at each point in time, regardless of which time it is now. Even if interesting new doors are opened on the side of *theory*, however, one might worry that hard presentism has problematic consequences for *experiment*. If there are no truths about the past, how can we justify the use of experimental evidence? If even the light in our eyes merely represents past things, and there are no truths to which those representations correspond, how can we believe in anything at all?

It will pay to draw on the notion of *quasi-truth* introduced by Sider (1999).[17] It is one thing to say that there is an underlying objective alethiology to which our statements correspond. It is another to say that we find some statements useful, and are justified in acting by them, while other statements can be safely ignored.[18] I argued in chapter 3 that a reasonable approach to indeterministic physics would result in a macro-scale *convergence* to approximately one possible past consistent with what exists presently. We can call this possible past 'quasi-true', and we can justify acting by it on the basis that worlds like ours *would* evolve from approximately that quasi-true past, *almost* all of the time.[19] This convergence is imperfect - the past remains *open* - but it should be sufficient for practical purposes in all but the most extreme of scientific regimes. I also point out in §3.5.1 that the shift from underlying truths to convergent possibilities is no worse an obstacle than the ordinary *epistemic* limits that scientists already grapple with. Experimenters are in the business of gleaning limited knowledge about what is or is not consistent with the fullest available evidence, and that mission never culminates in the discovery of a certain past truth. So we need not believe in the existence of such truths, in order to proceed with science.

The arguments of chapter 3 need not alarm the experimenter. What about the arguments from chapter 4? I highlighted that our scientific observations are representations of past events, though they are built from the evolving present. This implies that our observations may be unable to properly detect features of reality that depend in particular ways on their pastness, presentness, or futurity: namely, those that reduce to other properties or relations *when they are present*, but not when they are past. I do not believe this should be cause for panic, for

[17]Sider raises this in relation to the truthmaking problem, but he remains committed to tensed facts. See Markosian (2004) for another method, more closely related to hard presentism.

[18]Though truth *pragmatists* define the former as the latter. See Haack (1976) and Misak (2018).

[19]For more on justified belief without past truths see Ingthorsson (2019).

the simple reason that such features would be rare: copresentness, simultaneity, and the *shape* of the present are among them, but whether there are other examples is unclear. In general, then, I do not envision hard presentism as having revisionary consequences for scientific practice, though more research could be done on this issue. A plausible exception is in cases referred to above as 'the most extreme of scientific regimes'. One such regime is the quantum world: I have already investigated in chapter 5 how presentism could influence our understanding there. Another regime is that of the distant cosmological past, as flagged in fn. 63, §3.4.4. It could turn out that several macroscopic states of the early universe, just after the big bang, are equally consistent with how things are now. The hard presentist would reject that there is an underlying truth, or even a quasi-truth, among such alternatives. Finally, representations of states that are both *quite* far into the past and *quite* small in scale, such that they would leave little trace in the present, may also be cases where the absence of past truths becomes meaningful. There might be no truth or quasi-truth about what the first, microscopic life forms on Earth were, in so far as several similar creatures could have preceded the organisms and fossils that exist today.

6.2.3 Everyday Behaviour

If you are convinced of hard presentism, how should that affect your life? There are two related issues to consider here. Firstly, there is a normative question about what hard presentism *in fact* implies for how people should behave. Secondly, there is a descriptive question about how people would be *likely* to live if they adopted hard presentism. More research would be needed to answer these questions properly. In this section, I will merely suggest some examples of actions, priorities, and attitudes that hard presentism could realistically expect to have some bearing on, in either the normative or descriptive cases.

Firstly, one might think that abandoning past truths would mean abandoning much of our talk involving tenses and times. Should we cease to talk of what happened, or what will happen? Should you throw away your watch? The pragmatism and 'quasi-truth' discussed in §6.2.2 suggest that these are not reasonable reactions, particularly when our everyday lives are well outside 'the most extreme of scientific regimes'. In practice, it still makes sense to talk as we do, even if there are no absolute, underlying *truths* to which that talk corresponds. Times may not exist, but the Sun and Earth do, and if watches are useful tools in helping us to manage our lives around them then that is all the justification they require. Such pragmatism can plausibly extend even into fields where past truths seem intuitively important, such as the justice system. When the evidence is rolled out in a trial, *metaphysically speaking* there are no underlying truths to which that evidence corresponds. There is, however, a quasi-truth: worlds with evidence of this magnitude would generally tend to be worlds that would evolve from pasts where the accused commits the crime. There are likely several justifications that can be given to punish the accused on that basis, though I will not look into them in any further detail here.

Secondly, while a healthy dose of pragmatism might rescue hard presentists from these extreme ramifications, there remain questions about what hard presentists even regard as pragmatic or desirable. This metaphysics could plausibly affect our priorities and decision-making. If there is no past or future, should we massively discount the value of unreal 'future' payoffs, and prioritise the present instead? Should you live a reckless and imprudent lifestyle, under the mantra 'You Only Live Presently'?[20] Notably, there is an important feature of hard presentism that reckless imprudence clearly ignores. The presentist believes that reality is three-dimensional *and changing*. It does not follow

[20]I would like to thank Louis Lepper and Nick Jordan for our spirited discussions on #YOLP.

from this that one should aggressively prioritise happiness *now*, without any attention paid to how your happiness *changes*. In fact, even the most imprudent behaviour prioritises happiness in the short-term *future*, not in the literal present, so hard presentism would not obviously support such behaviour.

Thirdly, hard presentism could be conducive to shifts in attitudes towards memories of the past or predictions of the future. More broadly, it might lend itself to present-focused personal philosophies of the *mindfulness* variety. Eastern philosophies of this kind have been heavily used and abused in the West in recent decades,[21] so care would be required in understanding such views before any potential connections to presentist metaphysics could be understood. As a starting-point, it seems plausible that viewing the past as 'open' might affect our attitudes towards particular sorts of past grievances: namely, those with a minimal bearing on present life, where our only cause to linger is the pervasive thought that those events truly *happened*, long after any practical lesson has been learned. At the benign end, lingering memories of embarrassing moments that you have long grown up from, and everyone else forgotten about, might trouble you less for knowing that there is no reality or objective truth behind them. At the more serious end, I leave it to the words of Jan Łukasiewicz:

> There are hard moments of suffering and still harder ones of guilt in everyone's life. We should be glad to be able to erase them not only from our memory but also from existence. We may believe that when all the effects of those fateful moments are exhausted, even should that happen only after our death, then their causes too will be effaced from the world of actuality and pass into the realm of possibility. Time calms our cares and brings us forgiveness.
>
> (Łukasiewicz 1961/1967, pp. 38-39)

[21] This controversy is covered in detail by Walsh (2016).

6.3. Final Remarks

I believe that presentism is true. I find it so wildly implausible that the past or future are *out there* that I feel it would take extraordinary evidence to convince me of it. Neither the challenges from 'pure metaphysics' covered in the first half of this thesis, nor the findings from our best physics covered in the second, strike me as extraordinary evidence of this kind. That is not to say that these challenges, and the responses to them, do not lead to interesting findings. If my arguments from chapters 2 and 4 are accepted, then we find that there is no irreducible sense in which anything is past, present, or future, nor of which pairs of things are copresent or simultaneous. Instead, things just exist in three-dimensional reality, or they do not. If my arguments from chapter 3 are accepted, then we find that there are no truths about the past or future. At best, some representations of the past and future are more consistent with the present than others, but there are no underlying truths to which those representations correspond. If my arguments from chapter 5 are accepted, exploratory though they are, then we could yet find that reality is nonlocal, or that its evolution is heavily affected by the limits of a presentist ontology.

I believe that hard presentism is true. Just as it seems implausible to me that the past or future are *out there*, it also seems implausible to me that some absolute, objective code of truths about the past or future is *out there*. Instead, I think it much more plausible that we humans are, like everything else, three-dimensional objects in a state of *flux* or *change*, and that our records, memories, and observations, as well as our talk of truths, tenses, and times, are all merely part of our broader attempt to do the best we can in the three-dimensional world in which we live. Perhaps we can define certain things to 'be there': we can say that for any existing state of affairs X there is by definition a truth 'X is true', or we can say that for any pair of existing things A and B there is by definition a relation of copresentness or simultaneity between them. If such talk is useful to you, then by all means use it, but do not be alarmed if you find that such talk does not convert cleanly into talk of a *tensed* variety.

The 'stripped down' metaphysics supported in this thesis bucks a modern trend of resorting to extended ontological and alethiological baggage as a means of defending presentism. I regard this trend as contrary to the presentist project, which I characterised in chapter 2 as one of limitation and simplicity, avoiding commitments to expansive machinery like temporal axes or *times*. While there is controversy over whether there even *is* a unified presentist core, I still hope that the view expressed in this thesis is one that fellow presentists find appealing. Ultimately, the arguments made in each chapter are distinct from one another, even if they do all align with this 'simplifying' theme, so the reader could easily find some sections attractive, but others implausible. The overarching lesson that I hope to have communicated, however, is that a reduction of presentism to its ontological essentials is at least *often* a better way to proceed.

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