

1 Time Lost, Time Regained

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Cognitive science was born with a relevance to the metaphysics of time. Immanuel Kant's claim that time is imposed on experience by our cognitive architecture ("nothing but the form of inner sense") loomed over research into time in the nineteenth century. In this context figures such as Johann Friedrich Herbart, Gustav Theodor Fechner, Karl von Vierordt, Rudolf Hermann Lotze, Hermann von Helmholtz, Wilhelm Wundt, Ernst Mach, and William James performed and discussed experiments on time perception, much of which would now be classified as cognitive science or psychophysics. Most understood their psychological work as bearing on the truth or falsity of Kant's bold thesis—and hence saw cognitive science as relevant to temporal metaphysics.

Today research on time in cognitive science, neuroscience, and psychology is enjoying a renaissance. The last twenty years have witnessed an explosion of interest in the field. Due to increasing specialization and philosophy of time's long "linguistic turn," this work's connections to metaphysical issues are not as transparent as they once were. That doesn't mean, however, that such connections don't exist. This essay will describe some ways in which it has relevance. If I am right, cognitive science and related fields are at least as important as physics to temporal metaphysics. The mechanisms revealed by this research help us regain the time "lost" by physics, and in so doing, indirectly confirm some hypotheses in the metaphysics of time. After a brief setup, I describe the interplay between cognitive science and the three modes of time identified by Kant, namely, duration, succession, and simultaneity. I then sketch the beginnings of a solution to one of the main puzzles in the metaphysics of time, the so-called flow of time.

1.1 COGNITIVE SCIENCE AND TEMPORAL METAPHYSICS

It will be useful to borrow the "Kantian" framework Goldman (2015) uses when thinking about cognitive science's relationship to metaphysics. Goldman lumps

together the experiences, representations, and intuitive judgments that we have about the world into a category called “common-sense experiences.” Examples include seeing colors but also judgments about object persistence and number of objects.

What explains our common-sense experience? Goldman assumes that our common-sense experiences are a function of extramental reality, our cognitive engines, and cultural influences. In schema form:

$$CSE = f(R, COGEN, CUL),$$

where the abbreviations are the natural ones. The point Goldman wants to stress is that our common-sense experience is often not best explained by reality alone ($CSE = f(R)$) but instead reality plus our cognitive engine.

As a simple example consider the well-known Rotating Snakes illusion by Akiyoshi Kitaoka.¹ It presents a very powerful impression of wheels moving. The wheels are not actually moving, or so our “theory of reality” tells us. Here our cognitive engine comes to the rescue of our preferred theory of reality, for the illusion prompted scientists to discover mechanisms linking asymmetric luminance and the resulting differences in neuronal firing and adaptation rates to illusory motion. These mechanisms enable us to explain the gap between experience and what would otherwise be the best metaphysics of the image (i.e., no motion).

Let me make a few observations. First, Goldman’s goal with his framework is to show that cognitive science *can* be relevant to our understanding of reality. This claim is true and uncontroversial. The principle of total evidence dictates that we take all of our knowledge into account—including cognitive science—when forming beliefs about the world. Second, ideally we would amend the schema in a few ways. We ought to add the other sciences, such as physics and biology, we ought to clarify the “reality” category because we are part of it, and we may also wish to tease the category of common-sense experience into subcategories, separating the cognitive and the perceptual (to the extent possible). Third, our judgments are holistic. What we hold fast depends on context and our relative confidence in each hypothesis.

Restricted to time, common-sense experience is essentially identical with what I call *manifest time* in Callender (2017). See figure 1.1. Manifest time is not simply our temporal experience but a kind of regimented common-sense model of time, a model that psychology suggests we come to in late childhood. Tied to notions of identity, agency, freedom, and selfhood, it is tremendously important to us. Mellor (2001) appropriately calls it the *time of our lives*, as it is the model employed as we navigate the world.

¹ The illusion is available here: <http://www.ritsumei.ac.jp/%7Eakitaoka/rotsnake.gif>.

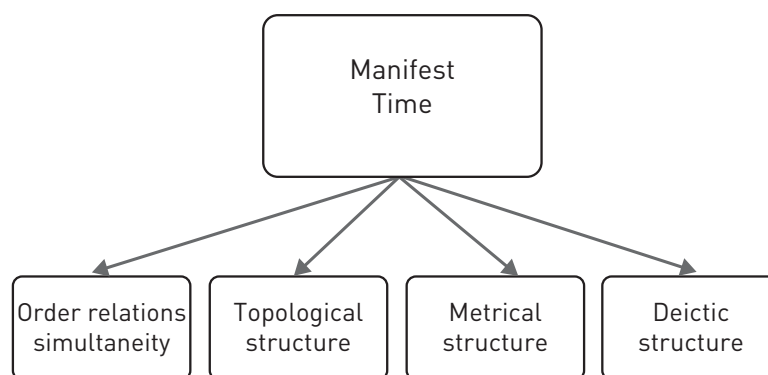


FIGURE 1.1 Manifest time. Manifest time is a somewhat rough-around-the-edges model of time that we naturally come to in development. The model treats time as having—at least—topological, metrical, and deictic structure.

Applied to manifest time, Goldman's schema is

$$\text{Manifest time} = f(R, \text{COGEN}, \text{CUL}, \text{etc.}),$$

where I've added "etc." to include the additional sources of knowledge one might draw upon, e.g., biology. In the Rotating Snakes illusion, we're confident in the background theory informing us that nothing really moves in the picture. That mismatch between reality and experience is one reason why it's an illusion. In the metaphysics of time, by contrast, the million-dollar question is whether there is mismatch. What do we substitute for R ? Do we assume that physics is essentially correct about time? If so, then manifest time and temporal reality disagree over some features. Or do we claim that physics misrepresents or incompletely represents time and replace it with a metaphysical model including features found in manifest time? If so, then allegedly manifest time is *detecting* a property of temporal reality.

Either way, I want to claim, we cannot ignore our cognitive engines and the other sciences. If there is mismatch, as in illusions, then cognitive science and other sciences obviously become relevant in explaining the mismatch. If no mismatch, philosophers are sometimes tempted to think our cognitive engines are irrelevant. This conclusion is wrong. There is no path straight from temporal reality to manifest time, nor from manifest time straight to temporal reality.

This point is an important one for the metaphysics of time. In my opinion the field regularly makes both mistakes and effectively assumes that $\text{Manifest time} = f(R)$. Going from left to right in the schema, the field often "discovers" temporal reality by reflection upon manifest time. The example of the Rotating Snakes illusion displays the danger here: by ignoring the contributions of our cognitive faculties, one may attribute to reality features that aren't there, e.g., motion in a still picture. Going from right to left, some philosophers assume that if a property is in reality, then its appearance in manifest experience doesn't require explanation.

Suppose, for example, that presentism—the claim that only present events exist—is true. Then there is a metaphysically distinguished Now. Manifest time includes a distinguished Now too, so the hope is that manifest time is detecting the Now. The job is only finished, I want to insist, when one explains how this detection works. No one has shown how such a Now impinges on our senses or shapes our judgments, a problem threatening to undercut the motivation for this metaphysics.² Our cognitive engines are always relevant, even in the most straightforward detection properties.

In what follows I want to fix “*R*” and then show how cognitive science is relevant if we’re going to explain manifest time. Indirectly this partly tests our choice of *R*, for if cognitive science (and etc.) can’t step up and account for manifest time, then that is a mark against our choice (*if* other theories of *R* can account for manifest time). I’ll assume that physics is correct and complete when it comes to temporal metaphysics. This is a big and controversial assumption—of course I may be wrong. Yet it’s worth seeing if we *can* explain manifest time without contradicting physics. Plenty of impressive evidence for physical time exists, and sticking with it is the most parsimonious option, as we need the temporal structure it posits to get back the rich successes of physics. By contrast, the evidence for the model described by manifest time is a bit of a mixed bag when it comes to features on which the manifest and physical models most famously conflict. What gets explained are primarily intuitions and it’s not even clear that the explanation is very powerful (see section 1.2).

With this default position, we ask: why do creatures model time as manifest if it is fundamentally physical time? Answering this question leads to cognitive science, neuro science, and psychology, but also evolution, our typical environments, higher-level physics, development, and much more. I’ll illustrate this with three modes of time, highlighting some of the surprising cognitive science involved. Then I’ll tackle the notorious flow of time, commonly said to be an illusion by physicists. I’ll sketch the beginning of a theory of flow that relies on our cognitive engines and much more.

1.2 SUCCESSION, DURATION, SIMULTANEITY

Neither manifest nor physical time is a commitment to one feature. Our concepts of time are multifaceted, committing us to order relations (e.g., one event being earlier than another), topological properties (e.g., time being open, continuous, connected,

² If the only property the Now has different from all other moments is bare existence, then you will have a hard time explaining how our senses detect it and our judgments notice it. This is a point I make in Callender 2011, 2017. Miller (2013) puts the point succinctly: “In making the privileged present empirically undetectable, it becomes very difficult to see how the presence of such a present could be the explanation for our temporal phenomenology, the very thing that motivates both views to posit a privileged present in the first place.” Stepping back, the complaint is similar to Benacerraf’s (1973) “no epistemic access” objection to Platonism about mathematical objects. Presumably an answer to Benacerraf, or to Miller and me, will rely in part on our cognitive engines.

oriented), and metrical features (e.g., the duration of events). Our common-sense picture crucially adds a flowing deictic structure of past, present, and future all relative to a distinguished moment (discussed below). Perhaps manifest time also includes immediate judgments about time, such as that the future is in front of us—in which case culture is relevant (Núñez and Cooperrider 2013).

Kant famously claimed that the mind imposed upon time three modes, succession, duration, and simultaneity. To warm up, let's see how cognitive science relates to these three core features of time. We'll find that temporal features are just like everything else we represent, namely, that there are plenty of examples of mismatch even when we have reason to think that a feature is part of reality and also represented, e.g., shape.

Start with succession, or temporal order. Unlike Kant, we're assuming that physics gets the essence of time right. By "physics" I'll mean general relativity, as that is our best science tackling space-time itself. Does relativity posit objective time order? Not for all events. See Figure 1.2. It does, however, posit an invariant and genuine time order between *timelike*-related events—events connectable by subluminal signals. Not all the events I perceive are timelike related to each other. However, I am a worldline of timelike-related events, so the temporal order of these perceptual events is fully objective. In addition, given the speeds involved, the time it takes to perceive, and that I'm often tracking enduring timelike objects, typically the objects of my perceptions are timelike related to one another too. I perceive the baseball pitch prior to the hit. Relativity agrees: not only is my perception of the pitch really before my perception of the hit, but indeed the pitch really is before the hit.

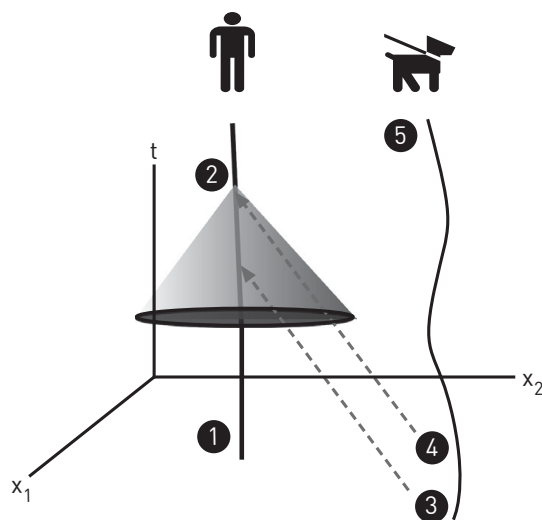


FIGURE 1.2 Person and dog in relativistic space-time. The past light cone at event 2 is partially drawn. Order: invariant time order exists on timelike worldlines such as the person and dog. Hence event 1 < event 2 and event 3 < event 4 < event 5. Event 2 is not before or after event 5. Event 3 happens prior to event 4 for the dog, and the person sees it so. Duration: invariant duration holds between events 1 and 2 and also among events 3, 4, and 5. How long the signals took to get from the dog to person is also invariant. Simultaneity: no pairs of events are objectively simultaneous.

Confident in relativity and mindful of the fact that creatures who get local temporal order badly wrong probably don't live long, I'm expecting that manifest time order is often a (fallible) detection of objective temporal order. Then the schema is

$$\text{Manifest time order} = f(\text{relativistic order, COGEN, etc.}),$$

where we suspect that manifest order is the result of detecting relativistic order.

That is not always the case, of course. Sometimes our experiences of temporal order don't mirror objective order. To take an unrealistic though vivid example, suppose I'm stargazing and see a supernova in the east and then a moment later witness a supernova in the west. The two supernova events are not timelike related and therefore temporally unordered, despite my ordered experiences. To explain cases like this we would have to resort to the invariant temporal order along my worldline. In addition, note with Kant that thunder is heard after lightning is seen, despite the two experiences being produced by the same event. Here again experienced order finds no counterpart in external events themselves.

Locally manifest temporal order tends to track objective temporal order. Regarding non-timelike-related events (like the supernova example), this is so simply because light is so fast. Imagine snapping your left and right fingers, trying to make the snaps non-timelike related. It's possible. But you will never know without the very best detectors that money can buy. Regarding signal discrepancies (like thunder and lightning) our local success is due to the discrepancies in signal speeds having less time to grow, but also from the brain's hardware and software using clever features to bind together signals from the same event source (see Callender 2017; Harris et al. 2010). For instance, fast auditory processing helps compensate for light's greater speed than sound, and mechanisms such as temporal recalibration help shift signal streams toward one another to aid binding. Our cognitive and perceptual architecture often gets it "wrong" (shifts an information stream) to get it "right" (recover the objective spatiotemporal map).

Experienced time order can be mistaken even without signal discrepancies. Suppose we present you with a low tone, followed by a noise burst, followed by a high tone. What will you hear? As Benussi pointed out over a century ago, typically one will hear instead a low tone, high tone, and then a noise burst. One hears the low-high together presumably because they form a natural gestalt, or psychologically salient whole form, and in this case, that trumps order (Benussi 1913; Holcombe 2013). A century later, scientists seem to have vindicated Kant's thought that judgments of causation can affect impressions of temporal priority. In an experiment that would cause Hume to roll in his grave (Bechlivanidis and Lagnado 2016), participants were presented with three objects, one of which starts moving before its cause. Participants claimed to have seen a temporally reordered sequence that matched the causally consistent sequence instead of the actual one.

Kant held that temporal order is imposed by the mind, not the world. Perhaps a modern Kantian might use these experiments to support Kant's order idealism. For me, impressed by the suite of evidence from the sciences and overall experience for objective time order, I instead hold fast to objective temporal order (among timelike-related events) and try to explain why our cognitive system may sometimes fail to register it. I learn that the brain seeking causation and gestalt can sometimes shape our impression of the space-time manifold, just as Rotating Snakes taught us about the odd effects of asymmetric luminance, patterns of neuronal decay, and motion. Helmholtz in 1881 (Helmholtz 1962) wrote:

It is just those cases that are not in accordance with reality which are particularly instructive for discovering the laws of the processes by which normal perception originates. [251]

This is exactly right. Mismatches between our experienced order and actual order help us understand how we track order as well as we do. Cognitive science helps us explain both detection of and departure from objective order, together aiding our theory that temporal order (along timelike paths) is objective.

Much the same can be said about duration. Duration is given by the proper time in relativity. Evaluated along timelike worldlines, the proper time is identical to the relativistic metric and therefore invariant. Physics—and not merely convention or psychology—assigns a temporal distance between my birth and my typing this sentence. Duration is not just in our heads. For the same reasons as above, we expect that

$$\text{Manifest duration} = f(\text{physical duration}, \text{COGEN}, \text{etc.})$$

will obtain. Manifest duration, we suspect, is a fallible detector of physical duration.

Again we find mismatch between the two. Durations measured by our heads are not in agreement with objective duration or even other heads. A film might seem long to you but short to a companion. Retrospective judgments about duration seem to vary with almost every imaginable variable (e.g., caffeine, alcohol, attention, excitement). Even short-term immediate impressions of duration can result in mistakes, as in the Oddball Effect. Present subjects with a stream of repeated stimuli, such as a picture of a shoe, all of the same duration. Randomly introduce a deviant object, such as an image of an alarm clock. Although the presentation of the alarm clock lasts as long as any one of the shoes, subjects tend to overestimate its duration (Pariyadath and Eagleman 2007). And as with order, judgments of causation can interfere with experienced duration (Eagleman and Holcombe 2002; Schutz and Kubovy 2009).

Despite all this variability, it seems clear that we're tracking objective duration. We use all sorts of temporal cues when estimating duration and with their use often can perform amazingly well. For long durations, even minus temporal cues, Campbell (1990) estimates that we judge each objective hour to be 1.12 subjective hours. For short durations Mauk and Buonomano (2004) claim we're usually within 10% of objective duration. Clearly a signal is fallibly being detected—in the absence of cues, at least by monitoring one of our many biological clocks. How these biological clocks work is still something of a mystery, but there are many models developed. And we can test whether, say, prediction or attention makes an oddball an oddball, thereby helping us discover the mechanisms at work. Once again, cognitive science explains both detection of and departure from reality in common-sense experience.

Simultaneity is different. If relativity is right, there is no temporal structure corresponding to simultaneity. It's just not there. Manifest time, by contrast, does appear to include simultaneity. I snap my left and right fingers together. I can tell whether they happened at the same time or one after another. The extent to which this simultaneity is phenomenological is not entirely clear. Does simultaneity “pop out” (for some evidence that it does in limited situations, see Van der Burg 2008)? Or is it a second-order judgment based on comparing two events? If we teased apart judgments and phenomenology within “manifest time,” it might be debatable where simultaneity is best classified. Nonetheless, however understood, subjective simultaneity belongs in the wide category of manifest time.

How do we explain manifest simultaneity if reality doesn't include objective simultaneity? Ask physicists and they will tell you that the physics of objects traveling at low relative velocities compared to the speed of light (like us and everything we encounter) can be approximated with classical physics. Classical physics possesses invariant simultaneity structure. That observation is true and important, yet all it really says is that physical systems can sometimes be modeled *as if* simultaneity existed.³ To fully explain manifest time, we need to look at the physical objects in our environment and our cognitive engine and see what actually produces our simultaneity experiences. This task initially seems an uphill one because cognitive science reveals a truly unexpected amount of intersubjective variability.

Consider the case of patient PH (Freeman et al. 2013). PH is a retired pilot whose vision and hearing became desynchronized due to a small stroke. PH will hear you say “Hi!” and only after a consciously noticeable lag see your lips move in the appropriate manner. Experiments confirm his subjective experience of hearing people speak before seeing their lips move. He was tested with a battery of time order judgment tasks. These are tasks where a subject is asked to report whether two stimuli occur before or after each other, e.g., what came first, the visual signal or the sound? Throughout the test the stimuli are presented across a range of discrepancies, from

³ For much more detail on the physics, see Callender 2017; Hartle 2005.

sound first to light first. For PH, lip movements lagged voices. To generate subjective simultaneity for him, voices need to arrive more than 200 ms after lip movements.

Interestingly, the lag had to go in the opposite direction roughly 200 ms to maximize the McGurk illusion for PH. The McGurk illusion occurs when mismatching lip movements cause one to hear the wrong phoneme. For example, mismatched lip movements can change an audio input of /ba/ to a heard /da/. Here one is reporting on some phenomenology—hearing a /ba/ or /da/—and not simply judging before or after as in a time order judgment task. Given the time order tasks, one would expect that the illusion was maximized for PH when the sounds were delayed after the lip movements. Not so! To maximize the illusion for PH, the mismatched lip movements need to arrive more than 200 ms *after* the sounds. PH’s “now” isn’t as unified as we might think.

If you run into PH you might not agree with him on what happens at any one moment. For you the noise “Hi!” and the lip movements appropriate to that might be in sync, whereas for him they may not be. Though not tested, perhaps you will also disagree on whether a finger-snap happened at the same time as the snap sound. And you also may disagree on what you heard, a /ba/ or a /da/, given some asynchronous gaps in signals. PH is something of an outlier. Perhaps the most surprising finding about PH, however, is that he is not much of one. Healthy subjects were given the same tests by Freeman et al., and the intersubjective variability was very high. Some subjects in the time order tasks needed lag or lead times as high as 200 ms too. Most also showed this strange pattern of a negative correlation between the time order judgment task on subjective simultaneity and what maximizes the McGurk illusion (and a similar Stream-Bounce Illusion). Many subjects even consciously noticed the lag times they reported. All of this fits what we’ve seen elsewhere in many other studies. For example, using simultaneity judgment tasks—which ask subjects whether two stimuli are synchronous or not—Stone et al. (2001) found that the point that maximized judgments of synchrony varied considerably. For maximum synchrony, one observer needs sounds to precede flashes by 21 ms, whereas another needs flashes to precede sounds by 150 ms.

In general, we’re not grabbing together as subjectively simultaneous precisely the same events. Pick a moment and take a perfectly accurate inventory of what is experienced at that moment. You and the person next to you may have very different events on your lists. And given the way asynchronous inputs affect phenomenology—as the McGurk illusion shows—the experience may be different even if you agree on inventory: for instance, your friend may hear /ba/ when you hear /da/.

Where should we find manifest simultaneity in all of this variability? Fortunately, in ecologically valid situations (i.e., ordinary life), we don’t much notice this intersubjective variance. Most of the events we discuss and care about are more coarse-grained than the blips and flashes presented to subjects in a lab. Think of a finger-snap. The middle finger slides down the face of the thumb and then makes the noise when slapping the fatty part of the thumb near the palm. In an ecologically

valid setting, you're not really going to notice whether the sound came at the same time as you saw the finger slap the fat part of the thumb. Suppose a person in a room snaps her fingers and you hear a snap sound, 100 ms before or after the visual impression of the snap. First, thanks to the processing differences between audio and visual perception, plus a large and malleable window of temporal integration, you may well experience the visual impression and the sound together. Second, as mentioned, even if you fail to bind them together, if the lag is slight and you're not looking for it, there is very little chance that you won't think the finger-snapping caused the snap sound. Third, as events get longer, our points of subjective simultaneity tend to converge. One study increased stimuli length from 9 ms to 40 ms, and then from 40 ms to 500 ms (see Boenke et al. 2009). As duration increased, agreement on simultaneity increased.

PH and intersubjective differences generate interest. Nevertheless, the bigger story here is that despite all this variability, when time scales get longer, events are salient, distances are small, relative velocities tiny compared to the speed of light, and much more (see Callender 2017; Hartle 2005), agreement tends to happen. Physical reality does not contain simultaneity. Cognitive science plus supplementary features of nonfundamental physics, local environments, and so on help explain manifest simultaneity.⁴

In sum, in all three cases—simultaneity, duration, order—our cognitive engines are relevant to our physical or metaphysical hypotheses about reality. The role they play depends on background theory. In the first two cases where we believe common-sense experience detects a property in the world, our cognitive engine helps explain how the detection works and also departures from it. In the third case where we believe there is no such property in the world, our cognitive engines help answer the question of why we nonetheless feel that there is such a property, namely simultaneity. In all three cases our cognitive engines play an important role in the holistic judgments underlying our theory of reality.

1.3 TEMPORAL DEICTIC STRUCTURE

One of manifest time's most important properties is temporal deictic structure. See Figure 1.3. In our conceptualization of time, we can characterize temporal

⁴ We're essentially following the method Christoph von Sigwart employed in his monumental *Logik* (1873; von Sigwart 1895). There he made a case for an objective time system in addition to Kant's subjective time. How would we find a time system common to all? His answer: simultaneity. Objective simultaneity is obtained by "reducing the Now of one man to comparison and coincidence with the Now of others." You and I are both simultaneously conscious of the same fact, e.g., a bird singing. This correspondence, Sigwart says, must be due to "external perceptions which are shared by all, and which occur simultaneously for all." Unfortunately for Sigwart, subjectively we're not always aware of the same facts, and objectively, relativity has no simultaneity structure. Still, his methodology is sound: we're *almost* simultaneously aware of the same content, and this is good enough to ground manifest if not physical simultaneity.

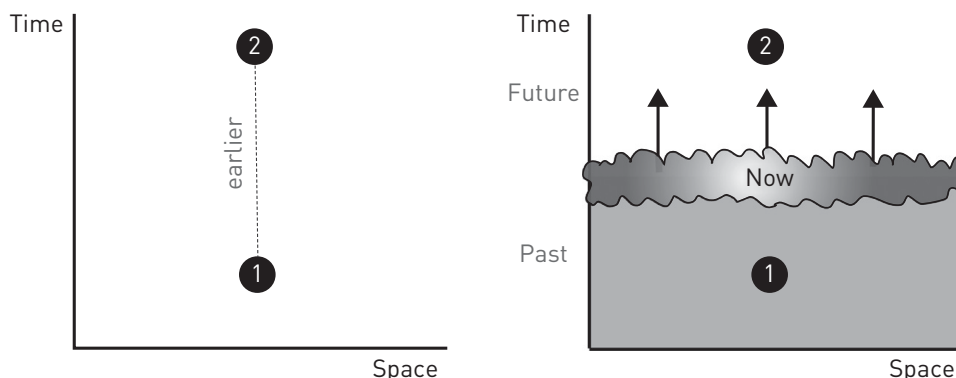


FIGURE 1.3 Sequential vs deictic time. Sequential or B-series time is depicted on the left. Event 1 < event 2, and a certain duration exists between them. A deictic or A-series time is depicted on the right. Superimposed onto sequential time is a distinguished Now that imparts a tripartite structure onto time of past, present, and future. The Now moves toward later events. Relative to the Now depicted, event 2 is future, while event 1 is past.

relationships either by reference to the present moment, or Now, or simply to another moment in the time series. The former conceptualization leads to a classification of events in terms of past, present, and future, whereas the latter leads to one in terms of the earlier than relation. Over a century ago McTaggart (1908) dubbed the first conceptualization an *A-series* and the second a *B-series*. Meanwhile in semantics and cognitive linguistics the first is sometimes called *deictic time*, referring to its need for a deictic center, the Now, which is typically the time of utterance, and the second is often called *sequence time*. The telltale difference between the two conceptualizations is that deictic expressions change truth value depending on when they are said, whereas sequential expressions do not. For instance, “Socrates will drink hemlock” was true only before Socrates drank hemlock but false afterward, whereas “Nixon is before Carter” is always true.

It’s hard to overestimate how significant deictic temporal structure is to our lives. Our language, thought, and behavior are all tuned to it. Finding out that the meeting is five minutes from Now motivates action in a way that finding out noon is five minutes later than 11:55 a.m. will not. Agency is understood in terms of this time series. The past is fixed and the future open. We don’t think earlier events are fixed unless those moments are prior to the Now. Our preferences are deeply tied to this structure too: all else being equal, no one cares about the past headache as much as the impending future one; and when discounting the value of distant future goods, it’s distant *future* not distant *later*, as our discount functions march in sync with the Now. Deeper than all that, we think that *we*—our selves—are wholly present in the Now. Unlike spatial parts like hands, we don’t consider our temporal parts to be parts. No, we think we’re entirely squashed into each Now.

Physics does not require temporal deictic structure in order to succeed. There is no distinguished Now in physics. Without a Now, there is no temporal deictic center, no past, future, or flow. This rejection of temporal deictic structure is commonly held to be a consequence of relativity, but that thought rests on confusing

temporal deictic structure with sequence time, i.e., conflating the Now with simultaneity. Classical physics is committed to simultaneity but was never committed to a preferred Now. Physics has never employed deictic structure—spatial, temporal, or spatiotemporal. No Now, Here, or Here-Now is privileged. The only way relativity has made life “harder” for deictic time is that it eliminates the sets of simultaneous events that one might choose to distinguish and “animate” as a flowing Now.

Given deictic time’s importance, the metaphysics of time literature since 1908 has been dominated by the question of whether deictic structure has a counterpart in basic temporal reality that vindicates its importance and use (see Dainton 2001). So-called *tense* theorists, impressed with the significance of temporal deictic structure, propose scores of temporal models incorporating a flowing Now, including presentism, becoming, branching. Differing in detail, they are unified in proposing what is supposed to be an objective counterpart for the temporal deictic center found in manifest time. In essence, these models assume physics is wrong about time, either through a sin of misrepresentation or omission. Research is dominated by arguments for and against tensed models, most of it focusing on the coherency of these models.

In this essay we’re trying to give physics a run for its money when confronted by manifest time. Is it possible to explain manifest temporal deictic structure while assuming that it isn’t fundamentally in the world? In terms of our schema, we’re assuming the usual on the right-hand side and hoping that temporal deictic structure emerges on the left,

$$\text{temporal deictic structure} = f(\text{relativity}, \text{COGEN}, \text{etc.}),$$

much as it did for manifest simultaneity.

Explaining manifest simultaneity was less daunting. Facts about signal speeds, low relative velocities, temporal integration windows, etc., more or less straightforwardly gave us approximate physical and psychological simultaneity—and eventually manifest simultaneity. With deictic structure, it’s not so obvious how to “build” the deictic from the nondeictic. If we think about it linguistically, mindful of what we know about the essential indexical (Perry 1979), it seems to be a nonstarter.

1.3.1 Explaining the Flow

In approaching this difficult question, it’s important to sharpen our understanding of the goal. The issue isn’t so much getting the deictic out of the sequential but instead why the temporal deictic frame is viewed as an objective window on reality, whereas the spatial one isn’t. As we’ve seen, everyone tends to agree, more or less, on the inventory of (big, salient) events scattered across sequence time. The same is true of what we might call sequence space. We agree on adjacency, size, shape, distance,

and more. First base is 90 ft in a straight line from home plate, for instance. We can insert or occupy a deictic center in either sequence time or space, or both. The Now picks out a special moment of sequence time. The spatial here, or better, a particular orthonormal triad of vectors, picks out the origin of a spatial frame. With respect to this spatial center, we speak of forks being on the right, knives on the left, the table in front, the painting behind, and so on. The spatial here plays an important role in language, thought, and behavior too. Yet we're not tempted to view this window as objective, whereas it's almost irresistible to objectify the window associated with the Now. So, yes, we want to explain why we use temporal deictic structure, but the really crucial target is why we believe it has a worldly counterpart when we don't think spatial deictic structure has any.

Once we have an explanation of that question, two other targets emerge: accounting for the flow of time and for the fixity of the past and openness of the future. Many people mean many things by "flow of time." Here I simply mean that the tripartite structure {past, present, future} updates itself. Psychologically I don't think this is detachable from the tripartite structure itself. If that structure didn't update, there wouldn't be reason for an organism to employ it. For purposes of analysis, however, we can tease the two apart and explain one and then the other. I won't have time to tackle it in detail, but we also model the past as fixed and unchanging, whereas the future is understood to be open, ripe with possibility.

Summing up, we want to answer the following three questions:

1. Why is the temporal deictic frame viewed as an objective window on reality whereas the spatial one isn't?
2. Why does it monotonically update in one direction unlike the spatial one?
3. Why do we model the past as fixed and the future as open?

We'll begin with the first.

The question why we think the Now mirrors a feature of reality and the Here does not is easy to answer—at least at first pass. We have massive systemic agreement about the Now but massive systemic disagreement about the spatial here. The fork is on *my* right, but if you're sitting across from me, it's on *your* left. The rug is *below* me; but to someone standing on her head, *above* her. The model of space that objectifies a spatial perspective couldn't make it through dinner, never mind a lifetime of navigation. But the Now? We all agree on it. No doubt this wide intersubjective agreement tempts us to objectify the Now and the wide intersubjective disagreement about spatially perspectival discriminations does not similarly tempt us to objectify it.

That observation is important and correct, but it merely moves the bump in the rug to a new location. Now we want to know: *why* do we have so much intersubjective agreement about the Now?

A big part of the answer appeals to what we might call the *hard facts of life*, namely, very basic features of our physical environments and biological and psychological structure. When space-time is divided into space and time, space is three-dimensional and time one-dimensional. Barring objects in our way, we can travel back and forth in each of the three spatial dimensions but due to the lack of time travel we cannot travel back and forth in time. These two deep features of the physical world have ramifications for our movements in time and our mutual orientations. In particular, we can't rotate in time, whereas we can in space. By rotating 180 degrees, we can swap both left-and-right and back-and-front. Without a temporal counterpart of these actions, we can't bring ourselves through sheer rotation to disagree with reference frames in time. There is also a massive asymmetry between what we can know and cause along the temporal directions that is not mirrored in the spatial directions. At any event, I can only cause events in the future light cone of that event, not past light cone; similarly, what I can know about the past is very different from what I can know about the future. Neither of these deep features has spatial counterparts. Combine this observation with the fact that our brains are hardwired with significant differences between time and space. Some are so basic that we typically don't notice them. For instance, at any given place, I can have different mental states at different temporal parts, yet at any given time I don't have different mental states in different spatial parts. My left foot and right arm don't each have different beliefs at a time, for instance.

Together these hard facts help constrain the deictic centers for time in a way they don't for space. Deictic structure imposes an egocentric reference frame upon sequence time and space. The question is why we disagree on deictic centers spatially and not temporally. What I've called the hard facts of life explain a lot of that. There is widespread agreement, spatially and temporally, on the nondeictic structure of space-time. The difference is that with time, due to the hard facts of life mentioned previously, we're locked into a common temporal perspective. Using memory or anticipation, we can escape backward or forward in time. But in terms of immediate experience we're all stuck in the same perspective. We don't have spatial parts with different mental states that could disagree at any one time, and we can't move into positions of differing temporal perspective. It is as if we were all chained to one side of an indefinitely long table. Then we could talk of the right and left side of the table and be tempted to think they mark objective categories in nature. Without disagreement, it would be the natural hypothesis.⁵ In the case of time, with all of us locked into the same perspective, it is. *Due to this "locking," the temporal deictic frame inherits the agreement found among observers on events in sequence time.* The hard

⁵ Compare with Shoemaker (1996)'s point about the property heavy-to-lift. If I associate with bodybuilders and the infirm, then I'll notice the disagreement over what is heavy to lift and regard the property relationally. But if I associate with people who are similarly strong, I may be tempted to regard it nonrelationally. The same thing is happening with the Now, where here I'm associating with people like me perceptually (and otherwise).

facts of life represent significant constraints that break what is otherwise a symmetrical situation between space and time.

If the preceding is correct, then we have an explanation for why we tend to objectify the temporal deictic frame and not the spatial one. See Figure 1.4. The deictic center provides us with a tripartite division of the world into past, present, and future. The hard facts of life then force agreement on sequential time onto deictic time. Absent such spatial locking, we disagree over deictic space and aren't tempted to paint it onto the world.

Turn to flow. Manifest time is also committed to the temporal deictic center updating itself monotonically with time. We don't merely agree upon temporal perspectives at each moment of time; we also believe that *our* temporal perspective is *moving* toward the future. Some enduring thing is crawling up the worldline.

The best earlier attempts to explain the flow are memory-based accounts. These theories, defended by Mellor and others, point out that memories are constantly accumulating up one's worldline. Because we recall having memories, they can also have a nice nested structure that suggests temporal flow. But these theories seem to be missing something. Accumulation is important, yet there is nothing surviving change moving up the worldline.

If we stick with physics, of course, nothing is literally moving up the worldline. That doesn't mean we don't model things as if they do. To represent change, as Kant noted, we must "represent something as retaining its identity through the change" (Prosser 2016, 173). What is it that retains identity through time? It could be all objects, as Prosser believes, but I prefer to concentrate on what psychologists call the *sense of self*. With this self we can help ourselves to the Buddhist-inspired idea,

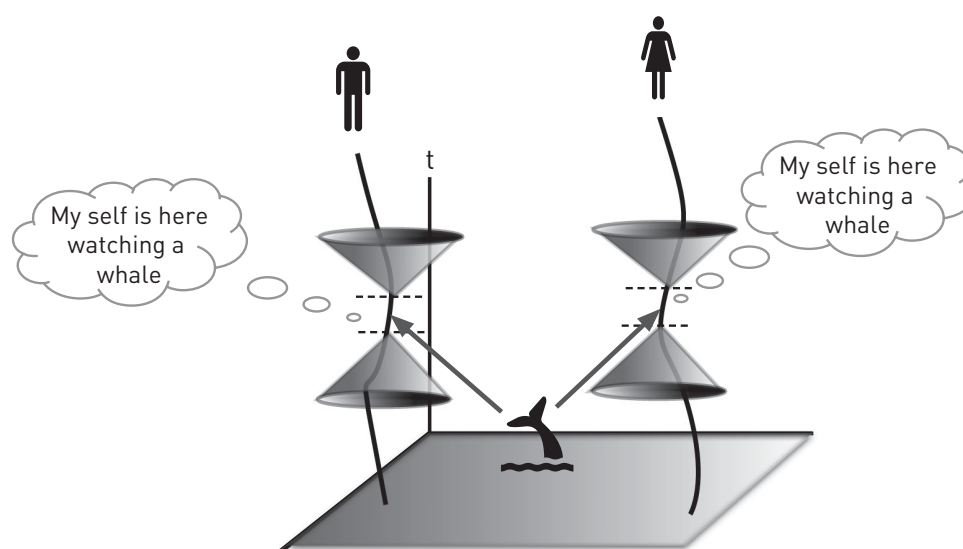


FIGURE 1.4 Building the Now. A man and woman watch a whale jump. Given signal speeds, processing times, and so on, they each have the jump event in their immediate experience, not memory. That is also where they consider themselves to be, as the sense of self is created from memories (and other psychological states)—it's the leading edge of memory. This situation holds for each psychological moment. In this way the man and woman share a common Now.

nicely captured by Velleman (2006b), that the “illusion” of the flow of time is due to the “illusion” of an enduring self. I find this theory appealing, and it can easily be connected to the preceding thoughts. My self is created (epistemologically and psychologically, at least) from my immediate experiences and memories. The self I form is one I regard as enduring, one that is selfsame through time and wholly present at each moment. At each moment, my immediate experiences are the leading edge of this self, the point where my memories run out. But this self changes continually, as moment by moment the threads of identity are weaved, the self retaining identity through time. To borrow a term we’ll encounter in a moment, we model ourselves as *moving egos* that endure.

Of course the nature of this self is highly controversial, both metaphysically (what facts, if any, determine who is genuinely who across time) and practically (what facts determine practical determinations of personhood across time). Since we’re focusing on why creatures model a certain way, not whether that modeling is correct, we need only focus on the practical problem. Here narrative theories of self are tempting. These are theories that attribute identity to the “story” we tell about ourselves. These theories are often advertised as being superior to traditional accounts based on psychological continuity and connectedness, for they add the self-creation that we employ but that traditional accounts lack.

What type of self do we need? The literature on selves, and in particular, narrative selves, is messy and runs across many academic fields. Very little agreement exists on what narration involves. The selves discussed range from very “thin” ones, momentary flickers of nonconceptual first-person content (Zahavi 2005), to highly conceptualized and even socially dependent “thick” conceptions, such as that one in high school is telling the story of a Goth and not an Emo (Schechtman 2007). In between are theories like Dennett’s (1992), which identifies the self as a fiction, like a center of gravity, a story determined by events that best explains what happens, and Velleman’s (2006a), which in contrast to Dennett’s identifies a self real enough to act causally. Due to the complexity of the issue, the question of the type of self needed for flow requires greater study than we can give it here.

Nonetheless, the answer is bounded from below very clearly: the selves need to be capable of reidentification over time. Lacking the possibility of reidentification, we lose identity and therefore an enduring moving ego. So very thin notions of a self incapable of reidentification, such as momentary first-person content, wouldn’t help us. Anything thicker than that, however, should work. Strawson (2004) complains about narrative theories that if I narrate whenever I just get a cup of coffee, then that sense of narration is trivial. Perhaps that complaint is aptly directed at some of his targets. When the point is to get time flow, however, that trivial sense may be enough; after all, time flows as we get coffee, not just when we construct elaborate narratives about ourselves as surfing philosophers. A thin notion of narration is probably all we need (perhaps so thin as to be questioned whether it qualifies as narration and not traditional psychological continuity and connectedness). A question that may

be interesting to consider is whether thicker notions of narration provide one with a richer notion of flow. Velleman thinks not, but the question deserves investigation.

Finally, manifest time paints the future as open, ripe with possibility, and the past as fixed and dead. Why? There are plenty of important temporal asymmetries in sequence time. Two prominent ones are the causal asymmetry, the fact that causes typically precede their effects, and the knowledge asymmetry, the fact that we know “more” about the past than future. Now graft an evolving self onto a world containing these asymmetries. This self provides us with a temporal perspective of past, present, and future sliding along sequence time. The self has a *sense of agency* over some of its actions. When it comes to it, the self chooses the blue shirt, not the red shirt, at the shop. Due to the causal asymmetry, its choices will be effective in one direction, again and again, moment by moment. With the temporal perspective intimately associated with these choices—the self makes decisions in the now—the self will learn not only that decisions *later* have effects and *earlier* do not but also that events in what it considers *the future* are alterable and in what it considers *the past* aren’t (Campbell 1994). For more along these lines, see Ismael 2011, and for how this connects with the temporal asymmetries of our emotions and preferences, see Suhler and Callender 2012.

Those, in brief, are the core ideas. Very coarsely put, we add an “indexical” element to the world, a temporal deictic center, and the physical, biological, and psychological constraints do the rest. The hard facts of life, plus facts about signal speeds, typical distances to one another, our cognitive engines, and more, together “lock” us in a shared temporal perspective, a view of the world as having a past, present, and future. Because it is shared and agreed upon, we paint this perspective on the world, unlike our spatial perspectives. Much the same causes us to regard the past as “dead.” Physical temporal asymmetries plus our cognitive engines constrain their temporal deictic center to see the entire future (and not just later events) as alterable, unlike past events. Evolutionary and cognitive pressures demand a sense of self. The hard facts of life then constrain this self to change very differently in time than in space, leading to the notion that the temporal perspective updates itself as the self does and makes the past direction unalterable.

1.3.2 Empirical Connections?

What would be nice to know is the extent that empirical science can be brought to bear on the preceding claims. Regarding the now and the dead past, I think empirical connections already have been made. What is less clear is what confirmation there might be for the new idea that the self is involved with the flow of time. Right now I see three potential points of contact, although readers may recognize others. I’ll briefly discuss two and mention one.

First, many claims are made about distorted experiences or conceptions of time and self among patients with various psychiatric or brain disorders, e.g., memory

impairment among schizophrenics. For instance, Martin et al. (2014) explore the possibility that disturbances in the conception of self are associated with problems in time processing among schizophrenics. Given all the confounds associated with the disorder, however, drawing definitive conclusions from these and other clinical populations is extremely challenging. In addition, many of these studies concern duration perception and other features unrelated to deictic time. See Craver et al. (2014) for a cautionary tale. For these reasons I haven't delved into this research yet.

Second, and directly connected to our work, is research in cognitive linguistics. Deictic structure has lately been a very active area of research there. Work looking for evidence of cultural variation distinguishes between two cognitive frames we employ when speaking and thinking about deictic time, the Moving Time frame and the Moving Ego frame (Clark 1973; Núñez and Cooperrider 2013). The difference lies in whether time is flowing toward or away from speakers. Is New Year's Day approaching? Or are we approaching New Year's Day? Experiments show great variation in what frames we adopt. These experiments are very interesting, but for our purposes, what is important is that we can switch back and forth between these two frames. This may require some effort, but it is not hard to do. How is this fact relevant to our theory of flow? Our theory states that time flow arises from the reidentification of the self through time. The theory gives us a Moving Ego. One might then wonder why we attribute to time itself dynamic qualities. The answer is that we can and do flip back and forth between Moving Ego and Moving Time frames. Cognitive linguistics backs up the intuition that once we get the ego moving, time's flow comes for free.⁶

Third, one may look at children's development of temporal concepts. Look at the roots of our mature A-series conception of time. We master an A-series conception of space or time when we can decenter. Decentering occurs when one adopts a different deictic center than one's own. With spatial decentering, I can say that the salt on *my* left is on *your* right. In doing so I adopt your spatial reference frame. No doubt I do this because I must be able to reconcile multiple spatial perspectives (given all the disagreement). Being able to do so in time means adopting different *nows*. The salt shaker was empty, now is full, and in the future will be empty again. The ability to shift this Now along sequential time is the crucial component of the temporal A-series. How do we accomplish this feat? In the spatial case we have

⁶ McTaggart seems to have noticed the difference between the Moving Time and Moving Ego frames: "It is very usual to present Time under the metaphor of a spatial movement. But is it to be a movement from past to future, or from future to past? . . . If the events are taken as moving by a fixed point of presentness, the movement is from future to past, since the future events are those which have not yet passed the point, and the past are those which have. If presentness is taken as a moving point successively related to each of a series of events, the movement is from past to future. Thus we say that events come out of the future, but we say that we ourselves move towards the future" (1908, 470).

all the disagreement, disagreement we lack (in the moment) temporally. The answer (roughly, and cutting a longer story short) must lie in our autobiographical memories, our memories “from the inside.” We can’t rotate around as we can in space and experience different spatial perspectives, but we can remember previous times that used to be Now. We can also anticipate times that will be Now. Thanks to these memories and anticipations, we entertain multiple conflicting temporal perspectives. Reconciling this conflict leads to understanding a Now shifting along sequential time.

If the picture sketched is on the right track, we might expect correlations among our (a) abilities to form a sense of self, (b) ability to temporally decenter, and (c) abilities to form autobiographical memories. The reasons to expect links are that self-creation draws on autobiographical memories for its story, hence a connection between (a) and (c), and that seeing oneself as temporally extended is plausibly crucial to temporal decentering, hence a connection between (a) and (b). As children develop, their abilities to form memories improves, leading eventually to a more mature conception of the self; with this self they can temporally decenter, leading to the conception of time as deictic or atheoretic. Whether this sketches the correct causal arrows remains to be seen, and other hypotheses may well predict correlations among (a), (b), and (c). Disentangling these abilities and coming to accept some diagnostic task as representative of each one is theoretically tricky (but there are plenty of proposals and tests for each already, e.g., the delayed self-recognition task (Povinelli 2001)). One could then search for correlations in performance on each task. Right now we have the tantalizing fact that interesting developments occur in all three abilities at roughly age four years old.

1.4 CONCLUSION

Illusory motion sends scientists on a search for its causes. The result is new science, the discovery of mechanisms and a better understanding of our system of motion detection. If physics is right about time, then the same process should occur for the explanation of manifest time. I examined how this works with succession, duration, and simultaneity. I then turned to the knotty problem of the so-called illusion of the flow of time. If illusory—or if not strictly an illusion but at least the failure to detect some fundamental feature of time—then it too should send scientists on a search for its causes. By dubbing it an illusion physicists take the flow and put its explanation on the desks of cognitive scientists, yet cognitive scientists don’t know it’s been placed on their desks. The job falls in the gap between the two desks. If anything like the theory of flow developed here is correct, this result is unacceptable: the explanation of temporal flow demands an all-out interdisciplinary attack. Philosophers knowledgeable of the psychological and physical sciences—and who have large desks—can help.

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