Reducing External Time

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Introduction

There is external time, and there is personal time. When David Lewis' character, Tim, travels into the past to try to kill his grandfather, he travels backward 56 years, from 1976 to 1920. (Lewis 1976) But, let us suppose, the trip only takes Tim an hour—an hour, say, has ticked off of Tim's watch. Roughly, Tim's watch measures Tim's personal time, which is different than the external time—56 years—through which Tim traveled.

There is external time, and there is internal time. Instead of Tim, let a non-person, like Tim's favorite plant, Eunice the eucalyptus tree, travel into the past. Suppose Tim positions Eunice in the time machine and pushes the right buttons. A watch around Eunice's trunk ticks off an hour, and Eunice travels into the past 56 years. The watch doesn't measure Eunice's personal time, because Eunice isn't a person. Instead, the watch measures Eunice's internal time.

The difference between external time and internal time is also apparent in the twin paradox. When one of the twins takes off in a rocket near the speed of light and returns to earth to reunite with her twin, she'll find that her twin's personal time has gone more quickly than hers has and that her personal time has elapsed more slowly than external time. Also, Eunice's internal time, if she were to take off in the rocket and return, wouldn't elapse as quickly as her plant twin's internal time, and, plausibly, her internal time has elapsed more slowly than external time.

Run the experiments for any object. The object has an internal time, and the object's internal time is different than what the external time is. Even if you think internal time and external time are extensionally equivalent because time travel is impossible,[1] what internal time is and what external time is are still different. And since things really can travel near the speed of light, as they do in the twin paradox, internal time seems extensionally distinct from external time.

[1]Keller and Nelson (2001) and Pruss (2013a) both argue that time travel is possible on an A theory of time.

In this paper, I'll argue for a view according to which external time just is a certain thing's internal time.[2] To do this, I'll first say something more about what internal time is. Second, I'll give a reductive view of external time, and third, I'll argue for the reductive view. My arguments will go like this: time is supposed to do some work. On the reductive view I've given, internal time can—and does—do all that work.

1 Internal Time

Personal time is a kind of internal time—it is just persons' internal time. The time traveler at one time, say Tim at 1976, is the same person as the time traveler at another time, say Tim at 1920. The continuity of identity between Tim at 1976 and Tim at 1920 is only with respect to Tim's internal time. There are many accounts someone could give of Tim's identity over time. For example, according to Lewis, this continuity has three conditions. First, there is, for the most part, only a gradual rather than a sudden mental and bodily change "in too many different respects all at once." (Lewis 1976, 147) Second, there isn't too much change from any one stage (Tim-1976) to another (Tim-1920), since many traits and traces last for a person's lifetime. Third, Tim's connectedness and continuity are not accidental. Rather, they "are explained by the fact that the properties of each stage [Tim-1976 and Tim-1920] *depend causally* on those of the stages just before in personal time, the dependence being such as tends to keep things in time." (Lewis 1976, 147) In short, any difference between Tim's relevant temporal stages is not too sudden, not too drastic, and causally connected in the right sort of way.

Lewis' view of personal time can be broadened to include non-persons. The internal time of an object is the time during which the following conditions obtain: 1) there is, for the most part, only a gradual rather than a sudden change in too many respects all at once, 2) there isn't too much change from one of the object's stages to another, and 3) the continuity of one stage to another is not accidental but is rather causally connected in the right sort of way.

Instead of adopting the modified (for internal rather than just personal time) Lewisian view, you can use your favorite view of object persistence, as long as the view of object persistence doesn't include reference to any times external to the object. For example, a view according to which an object A and an object B make up the same

[2]On my view, what internal time is and what external time is are different but external time just is some thing's or things' internal time. There are many things whose internal time is not external time.

object just in case A is at t_n, B is at t_{n+1}, and A causes B is ruled out, not only because it has counterexamples but because it includes reference to times external to the object's stages. A view according to which internal time is unanalyzable is allowed. You can even adopt a disjunctive view, or a view according to which persons and non-persons have different persistence conditions. An A-theorist may take internal time to be analyzable in terms of Real Change—change that is analyzable in terms of objective, global time. In any case, if you imagine a time traveling plant, you are imagining the difference between internal time and external time, so even if there is no analysis of internal time, in some cases at least it's easy to recognize it when you see it. The reductive view I'll give below is available to any view of internal time, so long as external time isn't required in the correct analysis of internal time, if there is a correct analysis.

2 A reductive view of external time

Imagine that internal time is the only measure of time. Would we have external time, too? Here's a view according to which we would: external time just is something's internal time. For example, suppose that during our lifetimes external time just is the internal time of some cesium atom or other from among the group of cesium atoms that behave in the relevantly similar way. Many cesium atoms have microwave light cycles that exactly mirror many other cesium atoms' microwave light cycles when they're in their ground state and undisturbed by external fields. These cesium atoms' microwave light cycles give us units for measuring external time.[3] So, the internal time of any of these cesium atoms, which we measure by their microwave light cycles, is a candidate for external time.

Cesium atoms' internal time isn't the only internal time that can be external time. If these cesium atoms (I'll call them "select cesium atoms") depart on a rocket traveling near light speed, either everything else speeds up due to no change in their powers, or some other thing's internal time is external time once the select cesium atoms depart.[4] To preserve the truth of our best scientific laws (more about this

[3]See Blair and Morgan (1968, 246-10–248-12). For more information on cesium atoms' microwave light cycles and how they are used to set the standard for our atomic second, see, for example, U.S. Navy Time Service Department (2013).

[4]For brevity, I'll use the singular "thing" instead of either the plural "things" or a combination thereof ("thing or things") throughout this paper to refer to anything or things whose internal time could be external time. I'll do this even though it may be that there are many things whose internal time is external time, because those things, like the select cesium atoms, have a relevant behavior that exactly mirrors the other things' relevant behavior.

later), we should take the latter option. If we take the latter option, some thing's internal time is external time until some relevantly important event occurs, after which some other thing's internal time is external time. Later, I'll say what events are sufficiently and relevantly important such that another thing or things' internal time becomes external time. These important events have to do with the work time is supposed to do. In the next section, I'll give some work time is supposed to do, and I'll show that all this work is done by the particular things' internal time that just is external time on the reductive view above. The requirement that time do this work will also limit what things' internal time can be external time in ways I will discuss later in that section.

3 Motivating the reductive view

What work is time supposed to do? In short, time plays a part in explaining some data. In this section, I'll give this data, and I'll show how this data is adequately explained, and often better explained, by the reductive view above.

First, time is supposed to play a part in explaining how two objects can be separated from each other even though they (are) in the same place: both objects (are) in the same place at different times. That two objects can be separated from each other even though they (are) in the same place can be explained on the reductive view above. According to the internal time of one of the objects, A, A (is) in a place P at t, and the other object, B, (is) in P at a time $\neq$ t. *Mutatis mutandis* for B's internal time. To do this explanatory work in the way I've described it, the internal time of one object needs to be correlated to the internal time of another. That is, A needs to have an internal time t that does not correlate with the internal time of B when B is in P. I suggest we do this in an Einsteinian way. Two internal times are correlated just in case that they're simultaneous, and simultaneity is relative to some other object's speed—in Einstein's case, the speed of light.[5] There are other ways to correlate the internal times of two objects. For example, if we assume that all causation is synchronic, one could adopt a causal approach on which two objects' internal times are correlated just in case they have the potential to affect each other at those times. As long as there is a way to correlate the internal times of two objects that is consistent, retains the truth of our best scientific laws, and doesn't require an external time distinct from any object's internal time, the reductive view can explain how two objects can be separated from each other even though they (are) in

[5] For objections to the relativity of simultaneity from quantum mechanics, I direct the reader to Michael Tooley's reply (and modification of Special Relativity) in Tooley (2000, ch. 11).

the same place.

Second, time is used to explain what (even Cambridge) change is. An object O (is) F at t_1 and (is) not F at t_2. This, too, can be explained on the reductive view above. According to O's internal time, O (is) F at t_1 and (is) not F at t_2. In fact, change is best explained on the reductive view. Suppose Tim is our object, and he starts to sweat 31 minutes (according to his personal time) into his time traveling trip from 1976 to 1920. At 1948,[6] Tim (is) sweaty, and at 1949, Tim (is) not sweaty. If there is an objective, non-reducible external time and if change is measured only by external time, then it is not the case that Tim (becomes) sweaty during his time-traveling trip. Rather, Tim (becomes) not sweaty. But it *is* the case that Tim (becomes) sweaty. According to Tim's internal time, he (is) not sweaty at t_30 (thirty minutes into his time traveling trip), and he (is) sweaty at t_31, where t_31 is later than t_30 according to Tim's internal time. (Also, according to this reductive view, according to some other things' internal time, Tim (becomes) not sweaty, but this is what we would expect.) So, a non-reducible external time is not needed to explain change, and there are counterintuitive results if non-reducible external time is the only time used to explain change.

Third, time is supposed to play a part in explaining some linguistic data. Suppose Tim, born in 1960, travels to 1920, tries to kill his grandfather, fails, doesn't do any more time traveling, and dies in 1958—before he was born. The 'before' in the previous sentence expresses a relationship in external time. How do we make sense the 'before'? In the reductive view above, we make sense of it along the timeline of whatever thing's internal time is external time—in the example above, the select cesium atoms.[7] Tim, 16 years old (measured by his internal time), appears on the scene at a certain intrinsic time in the life of the select cesium atoms: 1920. He dies at a later intrinsic time in the life of the select cesium atoms: 1958. He is born at

[6]Tim's trip, remember, takes an hour, so Tim starts to sweat around the half-way point of his trip. I picked 1949 because it is around the halfway point between 1976 and 1920.

[7]At 1920, there is a set of cesium atoms whose relevant behavior exactly mirrors other cesium atoms' relevant behavior. This set may be different than the set at 1960 of cesium atoms whose relevant behavior exactly matches other cesium atoms' relevant behavior. My claim is not that the set at 1920 is the same as the set at 1960 and that the intrinsic time of the atoms in that one set is external time. Rather, the claim is that the internal time of the cesium atoms whose relevant behavior exactly mirrors others' is external time, that the internal time of the cesium atoms meeting that description at 1920 is external time, and that the internal time of the cesium atoms meeting that description at 1960 is external time. The internal time is the same from 1920 to 1960, since the relevant behavior of cesium atoms in relevant group is the same from 1920 to 1960. I am assuming here that the relevant behavior of the cesium atoms in the relevant group in 1920 is the same as the cesium atoms in the relevant group in 1960. If it is drastically different, something besides these cesium atoms' internal time would be external time, for reasons given later in this section.

a later time in the life of the select cesium atoms: 1960. He disappears at a later time in the life of the select cesium atoms: 1976. The 'before' in the sentence above expresses the relation events in Tim's life have to the internal time of the select cesium atoms.

Fourth, time plays a part in explaining some scientific data. Our best scientific theories use equations that contain a time variable. This data, too, is best explained by the reductive view. The scientific laws on Tim's time machine don't reverse when Tim travels to 1920.[8] Rather, we substitute internal times into the time variables in scientific theories. Time variables used in the laws that hold on Tim's time machine are instanced by times from Tim's internal time or the internal time of Tim's time machine. If someone were to see Tim time traveling backwards (suppose his time machine is transparent), it would seem to her as if the laws were running backwards on Tim's time machine. For example, entropy decreases inside Tim's time machine from 1920 to 1976: Tim, from his perspective, gets a little older, but from the perspective of an outsider, Tim would get a little younger from 1920 to when he departed in 1976. This is what we would expect. The events the observer perceives on Tim's time machine are assigned times that correspond to the observer's internal time, and those times are substituted into the time variables in scientific laws.

Fifth, time is also used to explain the seeming directionality of our experience. There is a past and a present and a future, and in general we're headed into the future and we leave the past behind. There are several ways to explain this seeming directionality. I'll give three of these, and I'll show that these ways are best explained by the reductive view above.[9]

Some philosophers hold that the directionality of time is explained by the asymmetry in the second law of thermodynamics, which concerns entropy:[10] entropy is increasing in the future-direction. Can thermodynamic asymmetry be explained if the reductive view is correct? To do this explanatory work, the reductive view would need there to be something's internal time according to which entropy is increasing

[8] I take it that this is essential for something being a time machine. If the scientific laws were to revers when the Tim travels to 1920, much of the work a time machine is supposed to do couldn't be done. For example, Tim wouldn't meet his younger self, and he couldn't travel to before he was born.

[9] I won't give a counterfactual account of the directionality of time as Lewis does. After Kit Fine's (1975) counterexample to Lewis' (1973) account, Lewis (1979) uses intuitions about particular cases to develop rules that determine which worlds are closer than others to save his counterfactual account. I disagree with Lewis' intuitions about his cases, and his reply to Fine seems to me to be *ad hoc*. In any case, something similar to what I say about causation below could likely be adapted to address Lewis' counterfactual account.

[10] See Callender (2013) for a survey. For example, Skow (2007) argues that asymmetric scientific laws distinguish the temporal dimension from the spatial dimensions.

in the future-direction and for this thing's internal time to be external time. In the example from section 2, this thing is one of the select cesium atoms. Entropy is increasing in the forward direction of the internal time of the select cesium atoms.

Here's a problem: suppose the select cesium atoms were put in a time machine and the right buttons were pushed—the buttons that would normally send the occupants of the time machine back in time. Would it then be the case that according to our current scientific laws entropy would subsequently *decrease* in the forward direction? Plausibly, the answer is no. But this is a problem for the reductive view according to which the internal time of the select cesium atoms is external time. According to that view, our best scientific laws would be false if the select cesium atoms were to travel back in time.[11] Similarly, suppose the behavior of many of the select cesium atoms were to begin behaving erratically. Our best scientific laws would be false in this case, too; they would predict a much more erratic rate of entropy, for example.

Here's a solution: affirm that it's not necessarily the case that the thing whose internal time is external time is always the thing whose internal time is external time.[12] If the select cesium atoms' internal time is external time but the select cesium atoms time travel backward relative to most other things' internal time, to most other things the best scientific laws would be false. Perhaps we could add to our laws so they wouldn't come out false, but in this case they would be more complex and perhaps arbitrary (e.g. why would entropy start decreasing at such-and-such time rather than another?). We don't want scientific laws that are false, more complex than they need to be, or arbitrary. The things whose internal times are external time are such precisely because according to their internal times, the true scientific laws are as simple and as non-arbitrary as possible. It may be that true scientific laws are most simple and non-arbitrary if some thing's internal time is external time until that thing undergoes a certain event, and when that thing undergoes the event, another thing's internal time is external time. So if the select cesium atoms were to travel backwards in time, something else's internal time would

[11] One might argue that if the example of the reductive view in section 2 is correct, it would be at least physically impossible for the select cesium atoms to travel back in time. I don't think this reply is plausible. The select cesium atoms would at least be traveling backward relative to the internal time of almost everything else in the universe, which is enough, I think, to say that they've time traveled. I will, then, assume that cesium atoms, even on the view from section 2, can time travel.

[12] The 'always' refers to the entirety of the internal time of some thing(s) whose internal time is not external time. For example, perhaps during my lifetime the select cesium atoms will begin to time travel, and when (according to my internal time) they are time traveling, something else's internal time will be external time. In this case, cesium atoms' internal time is not always (according to my internal time) external time.

be external time, and this other thing would be such that both according to its internal time during and after the select cesium atoms' backward time travel and according to the select cesium atoms' internal time before their time travel, true scientific laws are both as simple as they can be and non-arbitrary.[13]

Here's an analogy to help support my claim that something else's internal time can begin to be external time. The standard for a meter used to be a stick in Paris, France. If the stick were to have broken, we would not have supposed that the meter had become different. If the meter had become different, everyone's measurements would be incorrect. Instead, something else would be the standard for a meter once the meter had broken. In trying to discover what the new standard is, we would not need to suppose that there is a platonic Meter that a concrete object needs to conform to. Similarly, if the select cesium atoms' microwave light cycles were to become erratic or to significantly differ from each other, external time would be reduced to something else's internal time. We would neither need to suppose that external time would become different or that there is a non-reducible external time that a concrete object's events measure. So there is no problem having two different objects be a standard for a measure, whether that measure is a meter or a second.

A different way to explain the directionality of time is by appealing to causation. Causation always happens in the forward direction of time. Of course, Tim's neuronal states cause his arm to move while he is traveling backward in time. There is also causation running in a different direction while Tim is backwards time traveling: events outside the time machine cause other events outside the time machine. If the direction of causation explains the directionality of time, it explains the directionality of internal time. If there is non-reducible external time and causation occurs only in its direction, then causation would be reversed in Tim's time machine. But surely if Tim were to travel backward in time, causation would follow Tim's direction, just as things obey physical laws according to their inertial reference frame. So, if the direction of causation explains the directionality of time, then non-reducible external time is not needed to explain the directionality of time.

Another way to explain the directionality of time is by appealing to the directionality required for moral behavior. The following seem to be moral platitudes:

a. If I make a promise, I am obligated to fulfill that promise in the future, not in the past.

[13]To be clear, I am not arguing that, necessarily, scientific laws are simple. It may be that the simplest scientific laws we have are quite complex. Further, if there were nothing in the universe but the cesium atoms and they went awry, on my view the scientific laws would be complex, arbitrary, or nonexistent in such a universe.

b. If I commit a crime, I deserve punishment in the future, not in the past.

c. It is better to have had severe physical pain in the past than to have severe physical pain coming in the future.[14]

d. I deliberate about what to do in the future rather than what to do in the past.[15]

These platitudes are accommodated just as well on the reductive view than on a view according to which there is non-reducible external time. Regarding (a), if I make a promise never to drink alcohol in 1976, I would be breaking the promise were I to time travel to 1920 and then start drinking alcohol, and if I get married in 1976 and time travel to 1920 soon after, I still have marriage vows to keep in 1920. There are, of course, some promises that I do, in fact, fail to fulfill by time traveling.[16] In all of these cases, though, I am still obligated to fulfill the promise even when I am time traveling. I have not gotten out of my commitment merely by time traveling, which shows that commitments follow the direction of the intrinsic time of the person who makes the commitment.

Regarding (b), suppose I commit a crime in 1976 and time travel to 1920. A government agent also time travels to 1920 and punishes me for the crime I committed in 1976. The government official should not be blamed for not having brought me to 1976 or later to punish me first. My desert follows my personal time, not external time.

Regarding (c), suppose I am now given the option of either 1) having undergone extreme physical pain 3 days ago and to have been given an amnesia pill so I would have forgotten the pain or 2) to undergo extreme physical pain in 3 hours personal time and to afterwards be given an amnesia pill to forget the pain. There's more. If I choose option 2, I'll take a one-hour backwards time-traveling trip to 1920, undergo the extreme physical pain in 1920, then travel forward in time to sometime after when I made the decision. Choosing option 2—time traveling then undergoing the pain—seems no worse than if I were not to time travel at all and experience the pain in the external future. I still would still prefer past pains to pains that are in my future, whether my future is in 1920 or 2013.

Regarding (d), if I time travel to 1920, I will deliberate about what to do when I'm there, even though 1920 is in the external past. 1920 is, in the time traveling

[14] For example, Gale (1996)'s T11 and S11.

[15] For example, Gale (1996)'s T4, S4, T5, and S6.

[16] For example, I can't fulfill the promise to call someone who is externally in the future, and I can't fulfill the promise not to time travel

scenario, in my internal future, so deliberation seems to follow internal time, not external time.

One other way to explain the directionality of time is epistemological. Most notably, there is the platitude that most of what we know about the future is based on what we know about the past. This platitude is the principle behind induction. This platitude, too, is best explained on the reductive view. We make inductive inferences about the external past if we time travel. When I'm in my time machine traveling backwards, I expect my internal future to resemble my internal past. When I push a button, I expect the button to depress. When I drop a pen in a time machine that is traveling backwards in time, I expect it to act either as it does when I take a train forward in external time or as it does when I take a space shuttle forward in external time. The platitude behind induction, then, seems to be a platitude about the internal time of the subject making the induction rather than a non-reductive external time.

4 Conclusion

Time is supposed to do some explanatory work. It's supposed to explain 1) how two objects can be separated from each other even though they (are) in the same place, 2) what a change is, 3) some linguistic data, and 4) some scientific data. Time is also supposed to explain a certain kind of directionality: the directionality of certain scientific laws, moral behavior, and inductive inferences. I've shown how all of this explanatory work can be done on a view according to which external time just is something's internal time. A non-reducible external time isn't needed to do any work. If a proponent of a non-reducible external time is to successfully defend her view, she has some work to do. First, she needs to find some explanatory work that a) time is supposed to do and b) is better done by a non-reducible external time than a reducible external time. Second, she needs to show that the explanatory work I have argued is better done on the reductive view above is either c) better done by a view on which there is non-reducible external time or d) not work that time is supposed to do. The proponent of a non-reducible external time may be able to do this, but if she is to do it, she has a difficult task ahead of her.

I'll conclude with two upshots of the reductive account I've given. First, the account above is Aristotelian. According to the reductive account, the work time is supposed to do is done entirely by things' internal time. To Aristotle, time is the measure of change, and changes belong to the substance that undergoes them.[17]

[17]Time is the measure of change: Aristotle, *Phys.* 219a9, 17-18, 219b2, 15-24. Changes belong

One plausible understanding of these Aristotelian maxims is that each thing has its own time that measures its changes. The reductive account above respects this understanding. There is no need for any other kind of time. If things' internal time supervenes on those things themselves, then, plausibly, time itself supervenes on the powers, liabilities, or actions of things—which is Aristotelian. (See Markosian 2013, 5)

Second, the reductive view provides an easy account of the rate at which time flows.[18] The rate that time flows for a thing is the number of units of that thing's internal time divided by the number of units of the internal time of the thing whose internal time is external time. Some things' time runs faster than others', but the things whose internal time is external time (if they travel at all) travel at a speed of one second per second. So not only does the reductive account above do the explanatory work that time is supposed to do, but it also provides an answer to how fast time flows, if it does in fact flow.[19]

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to the substance that undergoes them: Aristotle, *Phys.* 200b33-201a2.

[18]My account here roughly follows Pruss (2013b).

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