The story of the tablecloth: deriving "before" from atemporal notions

Abstract: This article develops a new account of the relation "before" between events. It does so by taking the set of all states of an object, irrespective of any presupposed order, and then ordering it by exploiting a characteristic asymmetry which appears on this set. It is shown that this asymmetry both implies temporal order, and is arguably also necessary for defining it. The upshot is that temporal ordering is a local phenomenon and requires no global temporal structure of spacetime.

Can the notion of one event being "before" another be explained in terms of something more fundamental? Or is it absolutely primitive? Several attempts to account for temporal precedence have been made. These include grounding it in thermodynamics (for an overview of this research tradition, see e.g. the references in Callender [2017], p. 244, footnote 4); Reichenbach's mark principle (Reichenbach [1956], ch. 23; cf. the discussion in Whitrow [1980], pp. 323-327); and causal theories, whereby causal priority accounts for temporal priority (e.g. Mellor [1998], pp. 105-117; Frisch [2013]). Here is not the place to discuss or criticize these approaches, although it is probably fair to say that a fully satisfactory account of "before" is missing so far. Rather, the aim of this article is to propose a new method for deriving "before" which, although extremely simple, has apparently been overlooked.

I will start with an example: Suppose you spill orange juice onto your table cloth. A moment later, and without interfering in the meantime, you spill wax on it. Considering the entire biography of the table cloth, you note that it features a state of the table cloth with juice and wax on it, and another with just the juice. Does it also feature a state with just the wax? It clearly could, for example if you decide to rub off the spot of juice.

If *T* is the table cloth, its state with just the juice will be written as *Tj*, and *Tjw* is its state with wax and juice. The order doesn't matter and has nothing to do with temporal order: *Tjw = Twj*. The events producing *j* and *w*—that is, the impact of the juice and the wax on *T*—will be written in boldface as ***j*** and ***w***. Then, *j* and *w* can be viewed as records of these events. Moreover, underlining will signify existence, so that $\underline{Tj}$ is read as "state *Tj* exists". Finally, *bs* will mean "before or simultaneous(ly) with", whereas the word "before" is taken to mean "strictly before".

Now, take an atemporal perspective: You are given a stack of photos documenting all states in *T*'s biography, shuffled in any order. The set of these states will be called M_T. You quantify over it by going through the photos. Suppose that, having done so, you discover that there is a state with wax and juice, one with just juice, but none with just wax: $\underline{Tjw}$, $\underline{Tj}$, $\neg\underline{Tw}$.

What can you conclude from this configuration? It is a sufficient condition for event ***j*** occurring *bs* ***w***. Why? Suppose it did not: Then, ***w*** would occur strictly before ***j***. But then, there must be a state *Tw*, which by assumption there is not.

It is important to understand precisely what this condition says:

First, it is a sufficient condition, not also a necessary one: There are cases where ***j*** occurs *bs* ***w***, but we get configurations other than the above on M_T. For example, let ***j*** occur, rub *j* off *T*, and then let ***w*** occur: we get $\underline{Tw}$, $\underline{Tj}$, $\neg\underline{Tjw}$. Or, let ***j*** occur simultaneously with ***w***, and then let nothing interfere with *T* ever again: we get $\underline{Tjw}$, $\neg\underline{Tw}$, $\neg\underline{Tj}$. The reader will be able to think of more examples.

Second, some may object that the above sufficient condition only works if it is tacitly assumed that records, once produced, stay forever—an assumption which would render the account circular. But this assumption is not made. Rather, deleting records is explicitly allowed. In particular, suppose the objector comes up with the following scenario: ***j*** and ***w*** occur simultaneously. Then, rub off *j* and keep your hands off *T* forever: we get $\underline{Tjw}$, $\underline{Tw}$, $\neg\underline{Tj}$. The objector now points out that, if the above sufficient condition were right, this would imply that state *Tw* exists *bs Tjw*, whereas in reality *Tw* exists *after Tjw*. To this, I answer that the condition refers to an order of *events*, not of *states*: the configuration $\underline{Tjw}$, $\underline{Tw}$, $\neg\underline{Tj}$ implies only that ***w*** is *bs* ***j***. This is fully compatible with *Tw*, or indeed *Tj*, outliving *Tjw*.

Of course, this account is not only about table cloths. Rather, it is about objects with different states marked by different properties, and events associated with these properties being produced. These conditions apply to the world of relatively macrospic objects: a rocky planet with craters in it produced by meteorite impacts; a beech leaf, with different states marked by different colours; or a child learning the first words of its native language. They do not apply to the quantum world, with its very different identity conditions (cf. Lowe [2003], p. 78). Let *X* be a variable refering to such a relatively macroscopic object, ***p*** and ***q*** any events involving *X*, and *p* and *q* their records. Since we can apply the reasoning used above for the table cloth to arbitrary macroscopic objects, events, and records, we can write:

$\underline{Xpq}$, $\underline{Xp}$, $\neg\underline{Xq} \Rightarrow$ ***p*** *bs* ***q***.

Or, abbreviating the left-hand side as $A_X\,pq$:

(1) $A_X\,pq \Rightarrow$ ***p*** *bs* ***q***.

$A_X\,pq$ can be called a "*pq*-asymmetry" on the set M_X, and configurations of this type will be called "record asymmetries". This time, the order clearly matters: $A_X\,pq \neq A_X\,qp$.

It has now been shown that the configuration $A_X\,pq$, which is itself *atemporal*—it can be stated without reference to temporal order—guarantees a *temporal* relation between events. Note, incidentally, that none of this has to do with causal order. No relation of causal priority between the events or states in question was assumed. Indeed, the derivation of (1) would also work if, *per absurdum*, we assumed that spots appear on table cloths acausally.

But, it will be objected, it has already been shown that—to use again the case of the table cloth—$A_T\,jw$ is not a necessary condition for ***j*** *bs* ***w***. Thus, the before order between events cannot be accounted for in terms of the record asymmetry. This objection, however, overlooks something: Suppose $A_T\,jw$ fails to hold but, having observed *T*, you make the judgment that ***j*** is strictly before ***w***. You can do so only if there is a corresponding record asymmetry on at least a subset of the set of *your* states. To show this, let ***j*** and ***w*** again be the two impact events on the table cloth, ***j'*** and ***w'*** the events where light rays from ***j*** and ***w*** hit you, and *j'* and *w'* their records in you (*Y*). Clearly, no before order between ***j'*** and ***w'*** can be ascertained using subsets of M_Y which have no states with *j'* or *w'*, or which have only one of the states *Yj'*, *Yw'*. Also, subsets having both these states, but not *Yj'w'*, provide no asymmetry through which the relation "before" could be established. This leaves only subsets with *Yj'w'*, giving four combinations:

a. $\underline{Yj'w'}$, $\underline{Yj'}$, $\underline{Yw'}$

b. $\underline{Yj'w'}$, $\neg\underline{Yj'}$, $\neg\underline{Yw'}$
c. $\underline{Yj'w'}$, $\neg\underline{Yj'}$, $\underline{Yw'}$
d. $\underline{Yj'w'}$, $\underline{Yj'}$, $\neg\underline{Yw'}$

Configurations (a) and (b) are clearly symmetric and cannot be used to ascertain an asymmetric relation. (c) is sufficient for ***w'*** *bs* ***j'***, and so cannot be necessary for ***j'*** before ***w'***. (d) is sufficient for ***j'*** *bs* ***w'***, which in turn is a necessary condition for ***j'*** being before ***w'***. But (d) is simply $A_{Yj}j'w'$, the counterpart of the missing $A_T jw$.

In other words, we can replace a record asymmetry which fails to hold on the *M*-set of one object by one on the *M*-set of an *ersatz*-object. The point made here should not be confused with the cheap stereotype that temporal precedence is a "subjective" product of the conscious mind. For we could equally have used, instead of *Y*, a lifeless object, such as, say, a photographic plate. Rather, I submit that the relation "before" between events is an observable, just like other observables (position, charge, etc.), whose operational criterion is the record asymmetry.

We shouldn't of course just naïvely assume that the order of ***j'*** and ***w'*** must correspond to that of ***j*** and ***w***. However, note that in the above case, we can: First, ***j*** and ***w*** are on *T*'s worldline, so that their order is a relativistic invariant: you cannot measure it the other way round in your frame of reference, if you measure correctly. Second, all light rays are travelling through the same medium, air, in the same gravitational potential, so nothing jumbles the order of the light signals around. Where, on the other hand, we have two signals of different types (such as light and sound), or where two light signals travel through media with different indices of refraction (including gravitational ones), we have to make compensating calcuations. But doing so is no problem in principle.

We can now write:

(2) A record asymmetry on at least a subset of the set of states of *some* object is necessary for ascertaining a before order between events.

(1) and (2) together show that temporal precedence is intimately linked to the record asymmetry. Given this, it is striking that this asymmetry is apparently completely overlooked in contemporary philosophy of time.

However, what we have up to now is not yet fully satisfactory: we need a condition which is necessary and sufficient for "before", not just for *bs*. There are several ways of deriving such a condition, of which the following is perhaps the simplest: Consider the state *Tj*. It can be involved in events ***p***, leading to states *Tjp*, i.e. to second-level states of *T*. The set of all states of *Tj* (whether first-, second-, or higher-level) will be called M_{Tj}. Now, suppose one of these events, call it ***l***, is such that *Tjl* is indiscernible from a bare *T*, i.e. from a state without *j*. For example, ***l*** might be you rubbing detergent onto the spot of orange juice. But given this, is it legitimate to write such a state as *Tjl*, i.e. as an element of M_{Tj}? Yes, because it is after all *Tj*, and not any state of *T* whatsoever, which is involved in event ***l***. Now, we can rename ***l*** as ***j̶*** (which can be read as "anti-***j***"), and *l* as *j̶* ("anti-*j*"), so that *Tjl* becomes *Tjj̶*. Insofar as *Tjj̶* is a special case of a *Tj*-state, i.e. an element of M_{Tj}, it can be viewed as a state different from bare

T. Now, consider the set of all states of *T* where, unlike we did at the beginning of this article, we distinguish between bare states and states of the type *Tp~~p~~* (for any record *p*). This set will be called $\mathcal{M}_T$.

Tj~~j~~ can be involved in an event ***p***, leading to a fourth-level state *Tj~~j~~p*, and so on. Any interaction thus raises the level of a state, so that any state has a unique level all for itself. This does not mean that any level is filled: it could be that there is just a second- and a fourth-level state, but no third-level one. In any case, $\mathcal{M}_T$ is now totally ordered. Incidentally, this order can also be interpreted as one of inclusion, since any higher-level state includes all the records in any lower-level state.

Note also that, on $\mathcal{M}_T$, a difference in level corresponds to a record asymmetry: If *Tpq* and *Tp* are in $\mathcal{M}_T$, there cannot be a state *Tq*. If there were, the first level would have two occupants. Thus, we have a *pq*-asymmetry. Conversely, if there is a *pq*-asymmetry, i.e. if $\underline{Tpq}$, $\underline{Tp}$, $\neg\underline{Tq}$, then the two states which do exist occupy different levels.

Based on these considerations, we may define that the before order of any two events which involve a given object is provided by the record asymmetry, or equivalently, by the level of the states, on that object's $\mathcal{M}$-set. More formally:

(3) For any object *X*, events ***p***, ***q*** involving *X*, and their records *p*, *q* in *X*: ***p*** is before ***q*** if and only if *Xp*, *Xpq* are elements of $\mathcal{M}_X$.

Here, *Xp* and *Xpq* may also contain further records not explicitly written, but it is understood that *Xp* is a state without *q*.

We now need to check whether the before order defined in (3) is consistent with the notion of "before" as we know it intuitively from everyday life:

First, the condition "*Xp, Xpq* are elements of $\mathcal{M}_X$" provides a sufficient condition for ***p*** being before ***q***. To see this, note first that this condition implies that *Xq* is not in $\mathcal{M}_X$, as argued, so that we have a *pq*-asymmetry. Now recall that, on our earlier set M_X, the *pq*-asymmetry was sufficient for ***p*** *bs* ***q***, but not for ***p*** before ***q***: ***p*** and ***q*** can occur simultaneously, and then ***q*** is rubbed off, giving *Xp*. By contrast, on $\mathcal{M}_X$, such a state is written as *Xpq~~q~~* (again, the order of the records doesn't matter), so that, on $\mathcal{M}_X$, the simultaneous case does not satisfy the above condition, but rather has the configuration $\underline{Xpq}$, $\underline{Xpq\text{~~}q\text{~~}}$, with no *Xp*. Thus, we can exclude simultaneity, and ***p*** must be before ***q***.

Also conversely: for events ***p***, ***q*** involving *X*, if ***p*** is before ***q***, then *Xp* and *Xpq* are elements of $\mathcal{M}_X$, as is easy to see: For in this case, we first get a state *Xp*. Then, some event ***r*** involving *X* may occur, where ***r*** may or may not be ***q***, giving state *Xpr*. In particular, ***r*** may also be ~~***p***~~ (i.e. "anti-***p***"). And so on, for any events ***r'***, ***r''***, etc., and corresponding states *Xprr'r''*… Now, we let ***q*** occur and get *Xprr'r''…q*. This is an *Xpq* state, whether or not there are any *r*'s other than *q*, and so *Xp* and *Xpq* are indeed in $\mathcal{M}_X$.

Finally, since the *pq*-asymmetry on $\mathcal{M}_X$ is necessary and sufficient for ***p*** being before ***q***, it follows that if *Xpq* is in $\mathcal{M}_X$, but *Xp* and *Xq* are not, then ***p*** and ***q*** occur, but neither does so before the other.

In sum, I submit that the before order between events involving an object is reducible to the record asymmetry, or equivalently to the level, on that object's $\mathcal{M}$-set. Operationally, this level can be found by using *M*-sets of objects, very often *ersatz*-objects, and finding record asymmetries on them. Arguably, this is exactly what we do in everyday life, where typically our brain functions as the *ersatz*-object. After all, we do not have access to the past as such, but only to records of past events, which are *present* to us—a point noted already by Augustine of Hippo (*Confessiones*, XI, 27). Therefore, we must infer temporal order from what is not temporally ordered. As has been shown, this cannot be done without the record asymmetry. Now, the record asymmetry—and from it, the level—can be found by inspecting sets of states of objects in any order we please. Thus, these concepts don't presuppose any temporal order, and so definition (3) is indeed reductive and non-circular.

What about "bare events", ones which don't involve objects? Esfeld, for example, cites the example of lightning (Esfeld [2011], p. 35). I myself think that lightning too involves an object (such as a cloud, or the atmosphere), and that bare events don't exist. But however that may be, we now have a reductive account of the temporal order of events involving a given macroscopic object.

Also, what about the order of two events happening to *different* objects? Easy: take a third object (call it *R*), let it be hit by light rays from those two events, and find the order of these hits by checking through $\mathcal{M}_R$. This order is invariant. Then, use relativity theory to calculate the order of the two events in *R*'s frame of reference, and to find out whether the spacetime interval between the events is such that their order is invariant.

Finally, what does the derivation of "before" in terms of the record asymmetry mean for the larger discussion on the arrow of time in contemporary philosophy of physics?

First, the before order is, primarily, something local. It is, so to speak, where the object is, since it is defined in terms of its $\mathcal{M}$-set. Orders between events involving separate objects can then be found from local orders, as shown. Thus, we don't need a global temporal structure, and in particular no global hypersurfaces of simultaneity (as defendend e.g. by Unger and Smolin [2015], Craig [2001], D. W. Zimmerman [2013]) in order to account for temporal precedence.

Second, the before order is emergent: it is a feature of the relatively macroscopic world, where there are self-identical objects with different states, not of the quantum world (cf. E. J. Zimmerman [1981]).

Third, the later a state is in the before order, the higher the entropy in its surroundings will be. This is because higher-level states have more records of events, and each event tends to increase the entropy. But rising entropy only accompanies temporal order and doesn't account for it (cf. Dainton [2010], pp. 47-50; Price [1996], p. 17; Callender [2017], p. 244). The record asymmetry does just this.

Bibliography

Augustine of Hippo, *Confessiones*. <http://www.augustinus.it/latino/confessioni/index2.htm>

Callender, C. *What Makes Time Special?* Oxford University Press (2017).

Craig, W. L. *Time and the Metaphysics of Relativity,* Dordrecht: Kluwer (2001).

Dainton, B. *Time and Space,* 2nd edn, Durham: Acumen (2010).

Esfeld, M. *Einführung in die Naturphilosophie,* 2nd edn. Darmstadt: Wissenschaftliche Buchgesellschaft (2011).

Frisch, M. 'Time and causation', In Bardon, A., Dyke, H. (eds.) *A Companion to the Philosophy of Time,* John Wiley & Sons (2013), pp. 282-300. <http://faculty.philosophy.umd.edu/mfrisch/papers/time-and-causation.pdf>

Lowe, E. J. 'Individuation', In Loux, M. J., Zimmerman, D. W. (eds.) *The Oxford Handbook of Metaphysics,* Oxford University Press (2003), pp. 75-95.

Mellor, D. H. *Real Time II,* London and New York: Routledge (1998).

Price, H. *Time's Arrow and Archimedes' Point: New Directions for the Physics of Time,* Oxford University Press (1996).

Reichenbach, H. *The Direction of Time,* ed. by Maria Reichenbach, Berkeley: University of California Press (1956).

Unger, R. M., Smolin, L. *The Singular Universe and the Reality of Time: A Proposal in Natural Philosophy,* Cambridge University Press (2015).

Whitrow, G. J. *The Natural Philosophy of Time,* London and Edinburgh: Thomas Nelson and Sons (1963).

Zimmerman, D. W. 'Presentism and the space-time manifold', In Callender C. (ed.) *The Oxford Handbook of Philosophy of Time,* Oxford University Press (2013), pp. 163-246. <http://fas-philosophy.rutgers.edu/zimmerman/Presentism%20and%20Rel.for.Web.2.pdf>.

Zimmerman, E. J. 'Time and quantum theory', In Fraser, J. T. (ed.) *The Voices of Time* (1981), 2nd edn, Amherst, Mass.: University of Massachusetts Press, pp. 479-499.

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