A new theory of time

Abstract This article proposes an interpretation of time that incorporates both McTaggart's A-series and his B-series, and tries to cast it in a role that could be useful to physicists. This AB-series allows one, to reconcile special relativity with temporal becoming if the latter is understood as 'ontologically private', which is given a mathematical definition. This allows one to define a unit of becoming, as well as the rates of becoming. This article gives a picture of this interpretation.

1 AB-series time

Famously, McTaggart (McTaggart, 1908) identified two different series that characterize time. There is the B-series and the A-series.

> "Positions in time, as time appears to us *prima facie*, are distinguished in two ways. Each position is Earlier than some, and Later than some, of the other positions. And each position is either Past, Present, or Future. The distinctions of the former class are permanent, while those of the latter are not. If M is ever earlier than N, it is always earlier. But an event, which is now present, was future and will be past."

I won't follow McTaggart to the conclusion that time is unreal, but suggest that time is real and has both B-series and A-series characteristics.

The B-series is a series of times ordered by the relation of 'earlier-than' (or 'later-than'). The B-series is usually thought of as going from earlier times to later times. It could be argued the B-series is the kind of time that's most often used in physics. For example, both coordinate time and proper time are B-series. And the time parameter of the Schrodinger equation is a B-series. The B-series relations do not change. Also, going 'backward in time' in the B-series just means going to earlier times.

I would argue the A-series is also a part of a comprehensive view of time. It's inescapable that dinner tonight is first in my future, then in my present, and then in my past. In contrast to the B-series, the A-series values change. Also in contrast to the B-series, going 'backward in time' is undefined, on this view.

It's a Zen observation that "Time constantly goes from past to present and from present to future. This is true, but it is also true that time goes from future to present and from present to past." (Suzuki 1986), p. 33. The former is the B-series (interpreted as 'earlier-times to later-times') and the latter is the A-series. Instead of saying 'time goes from past to present to future', we'd say 'time goes from earlier times to later times as it goes from future to present to past'. As later and later times become present, time appears to go on.

The question is how to incorporate the A-series in physics, while of course retaining the B-series, into what might be called the AB-series. The ideas here are somewhat related to Tense Realism, Perspectival Realism, and Fragmentalism, (Hare 2010), (Fine 2005). The idea will be to add to each system a 'now' and a 'becoming' (of the A-series) that is ontologically private to that system, while retaining the ontologically public B-series interrelations already in wide use in physics.

2 Ontological privacy

An ontologically private parameter may be defined as one that takes on a definite value when a system S specifies its own ontic state, but does not take on a definite value when a different system

specifies S's ontic state. This could be because, for the other system, 1. there is no such parameter, 2. there is a parameter but is doesn't have a definite value, 3. there is a parameter and it has a definite value but it is not known or knowable, for some reason, as might be useful in Qbism.

3 Panpsychism

I am conscious, and this is certain to a degree even greater than the certainty that there are physical laws on salient interpertations. But there is in one sense nothing special about my composition —I'm made of electrons and quarks etc. Thus there is good reason to think that the basic elements that make up my brain are accompanied by the basic elements of subjective experience—qualia. One is lead to the hypothesis that an electron is accompanied by a quale—a subjective experience—for example, the color green. Perhaps a muon is accompanied by a blue quale. There's been an amount written about this and surrounding ideas but the basic idea is clear enough and is called (dualist) Panpsychism. (Stanford 2017). (Other correlates to qualia such as complexity could be entertained.)

A quale may be construed, on most readings, as an ontologically private thing. For example, I may experience what I know as 'green' when I look at the leaves of a tree. But I cannot know that you experience the same quale (i.e. what I would call green) when you look at the same leaves. This observation shows my quale has a definite value for me, but not for you, and vice versa.

Some notion of temporal becoming is often supposed to be a feature of the A-series view. Becoming, for the purposes of this paper, is that flow by which an indexical clock (defined below) is first future, then *now*, and then past. Becoming is sometimes understood phenomenally. (Loury 2016). If panpsychism is true and temporal becoming is phenomenal then arguably every system experiences becoming. *e* (defined below) is well-defined in the sense that an interval of 1 second of B-series clock time is defined for a protozoan just as well as it is defined for a human, e.g. Alice, even though the protozoan doesn't have the mental resources of Alice. It's plausible that it's the same way with 1 *e* of A-series becoming.

4 New symbol, indexical clocks, the unit of becoming, rates of becoming

Mathematicians were taking square roots of positive numbers, e.g. finding x in the equation $x^2 = 1$. But one wanted to generalize to equations like $x^2 = -1$. There was no real number that did it, so to a real number Cardano added a non-real parameter *i.* That is, *i* is a kind of standardized place-holder for a would-be root, whatever the correct definition would eventually turn out to be.

So, one thing to try is: to a parameter *t* whose unit is a change in indexical clock time, for example, a second, add a parameter *e* whose unit is not an interval in B-series clock time. In AB-theory *e* would be of the A-series, a unit of what temporal becoming is like per second, as a kind of standardized place holder.

Define an *indexical clock* to be a clock that's not accelerating, has relative velocity 0, and is spatially local, to a centered inertial reference frame.

Try the definition

1 *e* is what temporal becoming is like for 1 second of indexical clock time

If becoming is indeed phenomenal, then it *must* be defined ('referred to') in this curious 'what it is like' way. This is how qualia must be defined, on salient views. E.g. a green quale is defined as 'what it is like' to experience green. The necessity of doing this has to do with their ineffability. *e* can be well-

defined across systems. 1 second is well-defined across systems such as Alice and a protozoan, even though the protozoan doesn't have the mental capacities Alice does. It's plausible that it's the same way with 1 *e* of A-series time.

For imaginary i we have $i^4 = 1$. What is the relation between *e*s and seconds? If the fourth power of one were to give you the other then it could be argued the complex numbers model time in AB-theory.

Define

1 sec./*e* = d(Alice's B-series)/d(Alice's A-series)

is the change in 1 second of indexical clock time per change in *e*.

Consider the rate $r = 2$ sec./*e.* This can be interpreted as meaning there are 2 seconds of indexical clock time per unit of becoming. Presumably, the 2 seconds are in a series. That would seem to imply that, for 1 *e*, 2 seconds go by, so earlier-to-later relations would appear to go by faster.

Let the rate r be in units of sec./*e*. The general idea is this:

$r > 1$ B-series time appears sped up (earlier-times to later-times appear to be going by faster than normal)
$r = 1$ the change in B-series information per change in A-series information is given by 1 second of indexical clock time per unit *e* of becoming. This is assumed to be invariant across all panpsychist systems, the way 1 second of indexical clock time is invariant across such systems as Alice and a protozoan.
$0 < r < 1$ B-series time appears slowed down (as in relativistic dilation)
$r = 0$ B-series time appears stopped (but the appearance goes on)
$r < 0$ one appears (from *future* to *now* to *past*) to be going backward in B-series time

One may define d*r*/d*e*. e^2 would have something to do with the rate of becoming accelerating. e^{-2} would be something like *"*per unit of becoming, per unit of becoming".

5 Special Relativity

Four coordinates $(t, \boldsymbol{x})$ are not enough to schedule a meeting between Alice and Bob. Alice must also know if the meeting is to take place in her past or in her future. If it's supposed to take place in her past, she may have already missed it, and should act accordingly. If it's in her future, she may be able to make it, and can act accordingly. Alice can make a *prediction* about whether she'll make the meeting based on *future-now-past* information. So it's falsifiable.

I conclude Alice doesn't live in Minkowski space, but a larger space. Minkowski space doesn't have enough *information* to schedule a meeting. One needs something like $(g_j, t, \boldsymbol{x})$ coordinates for systems *j*.

As of this writing, Google have two temporal parameters by which one may filter a search for videos. There's 'Duration', the end of the video supposed to be that much *later* than the beginning. And there's 'Time', which might be, for example, one year before *now.* Similarly, YouTube has 'Duration' and 'This year', one year before *now.* There are two buttons. The thing is, how would you keep the same

functionality with only one button? This might be interpreted as a kind of *experimental* result: at least two buttons are needed for the temporal parameters. I don't see a way out for either the A-theorist or the B-theorist.

Alice orbits the earth and Bob is in the Andromeda galaxy. For some configurations, the planes of simultaneity of Alice change so that Bob is in Alice's B-series later than, simultaneous with, earlier than, simultaneous with, later than, etc...

"But (bringing the subject into the story) my *now* advances along my trajectory at one second of my personal experience for each second that passes on my watch, which follows the same trajectory as I do. And your *now* advances along your trajectory at one second of your personal experience for each second that passes on your watch, which follows the same trajectory as you do." Mermin, (2018), p. 33. We might be able to say Alice's *now* advances along her worldline in an ontologically private way at a rate of one second of personal experience for each second that passes on her watch. Also, Bob's *now* advances along his worldline in an ontologically private way at a rate of one second of personal experience for each second that passes on his watch. But, for Bob, it is not true that his *now* varies back and forth through his clock times, as Alice would have it.

The *now* is an empirical feature. Alice and Bob may agree on the order of all of their watch's ticks along each person's worldline—this is the B-series information. This information is effable. Yet Alice and Bob, in this view, may experience their own senses of *now*—the A-series information.

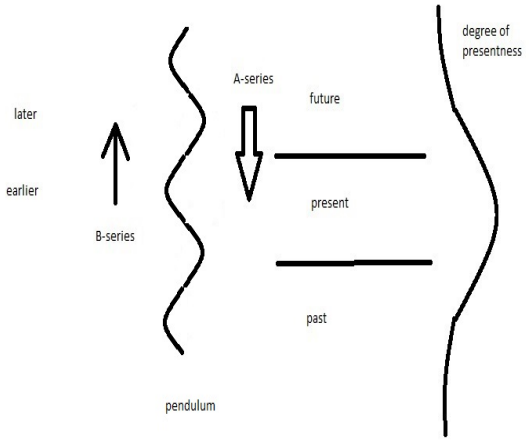
Simultaneity. I assume an explanation would go something like this. Alice, at rest relative to the train station, experiences one *e* of what her temporal becoming is like per second of her indexical clock time. Bob experiences one of his *e* of what his temporal becoming is like per second of his indexical clock time, who is at rest relative to the train, which is speeding by the train station. … As Bob goes by, Alice has it that his clock runs slower than hers, and vice versa. On one of the interpretations of 'ontologically private' these are all consistent because, for Alice, Bob's *e* has no particular value, and for Bob, Alice's *e* has no particular value. On another interpretation, for Alice, Bob doesn't even have a parameter *e*, and vice versa.

Are we allowed to just stipulate that? If becoming is phenomenal and ubiquituous then yes, yes, we can just stipulate that. That's because it's like the case where I can see green when I look at a patch of leaves but I don't know that you experience the same qualia (those which I would call 'green'), when you look at those leaves. When you look at those leaves you might be experiencing what I would call red, or even experiencing nothing at all. In some ontological sense I can't assign a definite (qualitative) value to what you see. So this is an example where phenomenology fits either of two of the above definitions of ontologically private.

6 Picture of AB-series time

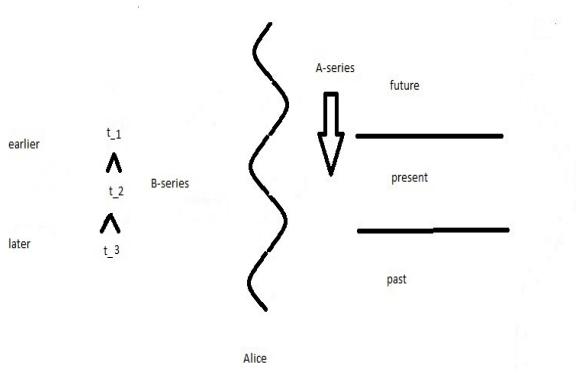
One doesn't need to suppose the present is a single infinitesimally small point centered at, for example, $t = 0$. For each t there could be a degree of 'existence' or 'actuality' or 'presentness' $d = d(t)$, so the *now* is spread out in B-series time somewhat. (Smith, 2010). One attractive example is for d some Gaussian function of t (in a centered world). Also non-symmetric functions.

A schematic of the AB-series picture of time would go something like



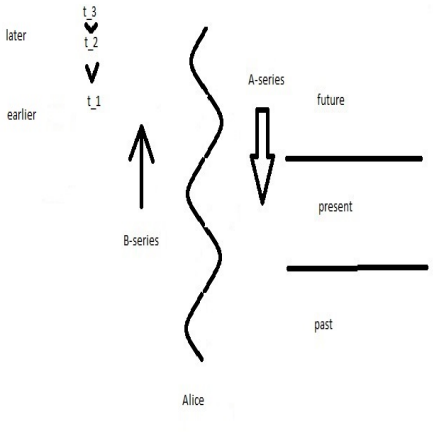
The earlier-time to later-time time-like worldline of a pendulum stays in one ordering (of one kind or another), but the whole worldline moves from future to present to past, with the present staying put. As later and later B-series times become present, time appears to go on.

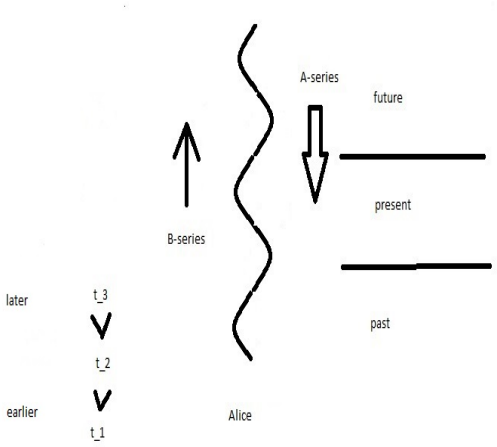
Time-reversal goes like



t_3 and then an earlier time t_2 and then an even earlier time t_1 become from Alice's future to her present and then to her past. As earlier and earlier times become present her, time appears to be going in reverse. Time-reversal invariance obtains only for a B-series, on this view. Time-reversal for an A-series is undefined. There's no unit defined of going backward in the A-series.

Two pictures





picture 1 picture 2

where t_3 is later than t_2, which is later than t_1. There are two parameters for one dimension of time. Minkowski space doesn't distinguish between picture 1 and picture 2. Ergo, Alice doesn't live in Minkowski space, but a larger space.

Minkowski space doesn't have enough *information* to schedule a meeting. One needs something like $(g_i, t, \boldsymbol{x})$ coordinates for systems j. One may define functions of these coordinates $k_j = k(g_j, t, \boldsymbol{x})$. The point is now that there are no functions of more than one system's private variables g_j, e_j, because these are ontologically private, by hypothesis.

One can chain derivatives if there's only one e_j. For example

$$\frac{d(\text{Alice's A-series})}{d(\text{Alice's B-series})}\frac{d(\text{Alice's B-series})}{d(\text{Bob's B-series})} = \frac{d(\text{Alice's A-series})}{d(\text{Bob's B-series})}$$

A function of a public parameter is public. A function of a private parameter is private to that system. A function of two public parameters is public. A function of a public and a private parameter is private to that system. There are no functions of private parameters of two different systems.

7 Seconds, position, experiment

The definition of a second is

> "The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom." https://physics.nist.gov/cuu/Units/second.html

One might say this duration (...) is an interval. It's irrelevant to this definition when *now* actually is. To *actually do* the experiment one cannot avoid the relevant A-series information (i.e. at some time it must come to pass that the physicist performs the experiment in his or her present). So, to make an accurate model of actually doing the experiment, the physicist must add A-series information to their model. How many bits does it take to specify the A-series information?

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The thing to do for the simple case of the point position of a classical particle is along this line.

For classical 3-dimensional position $\boldsymbol{x}$, one has $\boldsymbol{x}$ as a function of seconds, $\boldsymbol{x} = \boldsymbol{x}(b$ seconds). (I'll use 'b' instead of 't' for the number of seconds for reasons to become clear.) Let g be position of the particle on the *future-now-past* spectrum such that $g > 0$ means the particle is in Alice's future, $g = 0$ the middle of the present, and $g < 0$ past. The coordinate is standardized by the unit of becoming e_i. For the AB-series one has $\boldsymbol{x} = \boldsymbol{x}(a\ g_i,\ b$ seconds). The first coordinate carries the information a of how far in the future/now/past the particle is, for Alice. The possible world at a can be assigned a degree of existence/actuality/presentness d(a). The growing-block theorist supposes the past is real, which might be defined as d(a) = 1 for $a < 0$. The block theorist would have d(a) = 1 for all a. The presentist has d(a) = 1 for a = 0. This is generalized by the 'presentism function' d(a).

Notes

Time, in the sense that both the A-series and the B-series are needed, in turn, suggests that the dualist's qualia and matter are parameterized by two different variables, and they're probably not isomorphic.
…
There's a difference between e the unit of becoming, and g the location along the future/now/past spectrum, and t the interval of a second. Is there some relation between them, like $e * g = - t$?
…
It's not right to say time goes from 'past to present to future' in this AB-interpretation. Rather it goes from earlier times to later times, as it goes from future to present to past. As later and later times become present, 'time to goes on'.
...
A good candidate for being the most fundamental equation in all of physics is distance = rate * time, $d = r * t$. The time variable t is a B-series. Is the time variable in the rate also necessarily a B-series? If it's an A-series, this would change the interpretation of 'distance' to 'actual distance'.
...
One says, for example, let's meet at height meters, latitude 100, longitude 100, at the time t = January 1st, 2029. What this time really says is to meet at a time that is 2029 years *later than* year 0. The time coordinate doesn't have the future/present/past temporal information. This is witnessed by the necessity of having at least two buttons for the temporal parameters of videos on Google or YouTube.
…
There's a large and growing body of proposals for what the correlates ('correlates' given dualism) of the phenomenal are. If the phenomenal are correlated to something, for example, complexity, and there are relative amounts given by that complexity, then it may be that this would affect the 'amount' of seconds per e, a seconds/b es. That would then have the interpretation that the complexity of a system is correlated to the rate of becoming (i.e. the number of Bob's indexical clock seconds that go by per e of Alice).
...
Why not consider the entangled singlet state $|\Phi\rangle$ defined by

$$|\Phi\rangle = \frac{1}{\sqrt{2}}|01\rangle - \frac{1}{\sqrt{2}}|10\rangle$$

for two anti-correlated spins of electrons e1 and e2. Suppose Alice and Bob are space-like separated and e1 goes to Alice and e2 goes to Bob. When Alice measures the spin of her electron, is the spin of Bob's electron determined *instantaneously* or not? On the one hand, no. Nothing can go faster than light, and the electrons are space-like separated. On the other hand, yes. The present in which Alice measures e1 is the same present in which she instantly knows (infers) the spin value of e2. In the latter

case her future can't contain any states where the value for e2 is different than what Bob gets for e2.

In classical physics the position of a system is sometimes given as a function of time, $\boldsymbol{x} = \boldsymbol{x}(t)$. This time variable is a B-series. To incorporate A-series information one apparently introduces ontologically private time parameters g_j for each system j, indicating where on j's future/present/past spectrum the particle is. This makes the physics relative to the present of the observer. $\boldsymbol{x}_j = \boldsymbol{x}_j(g_j, t)$. For example the position of e1 relative to Alice might be location (1, 2, 3), when the indexical clock says 4 pm and when e1 is 3 seconds in the future of Alice. (In 3 seconds the clock will come into Alice's present and it will read 4 pm.)

If we equate the private parameters between e1 and e2, $g_i = g_j$, this has the interpretation that we are in the special case where Alice and Bob have the same *present.* In that case, Alice's inference of what e2 is, and the measurement of e2 by Bob, are simultaneous *and* in the same present. In this case the measurement by Alice of e1 does the job of the two measurements of e1 and e2.

Since Alice makes one measurement that is effectively two measurements, instead of Alice getting a result to her measurement '0' or '1' plus epistemic information as in the usual case, her one measurement reveals the whole system, with result '00' or '11', as the combined state hasn't been determined by Alice or Bob, or anything, until then. So in this case Alice doesn't measure '0' or '1' (plus epistemic information), which are 50% anti-correlated. In the special case, she measures '01' or '10', and these are 100% anti-correlated. By varying these two kinds of measurement one can get any probability in between. I think it could be argued that the measurement in this special case, represented by *one* operator (I think) on a Hilbert space, has ontological significance for e1 and e2. This is a non-local condition. Therefore this interpretation might produce greater-than-local correlations.

8 Conclusion

> "well, [time] is a bit of a mystery. I'd say we understand about half of it, and the other half is still yet to be explained." (Carroll, 2010)

The definitions of the B-series and A-series have teeth—B-series values (orderings of whatever kind) don't change on time-like worldlines, while A-series values do change. The B-series is ontologically public while the A-series is ontologically private, which has been given a mathematical definition and which allows it to be consistent with the relativity of simultaneity. If the AB-series view of this paper can be sustained, the A-series would be the other half Carroll referred to. In this interpretation of time there is one dimension of time per system (however 'system' is to be defined), and it has both A-series and B-series characteristics.

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