



# Your Brain Is a Time Machine: The Neuroscience and Physics of Time

*Dean Buonomano*

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The brain—the most complex dynamical system in the known universe—tells, represents, and perceives time in multiple ways. In this virtuosic work of popular science, neuroscientist and best-selling author Dean Buonomano investigates the intricate relationship between the brain and time: What is time? Why does time seem to speed up or slow down? Is our sense that time flows an illusion? Buonomano presents his own influential theory of how the brain tells time, and he illuminates such concepts as free will, consciousness, spacetime, and relativity from the perspective of a neuroscientist. Drawing on physics, evolutionary biology, and philosophy, *Your Brain Is a Time Machine* reveals that the brain's ultimate purpose may be to predict the future, and thus that your brain is a time machine.

## Your Brain Is a Time Machine: The Neuroscience and Physics of Time Details

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# From Reader Review Your Brain Is a Time Machine: The Neuroscience and Physics of Time for online ebook

## Michael Chow says

Unlike the other books I used to read in the past, this is a book that I picked up randomly from the book store and to my pleasant surprise turned out to be a great entertainment.

I tend to read books related to technology, engineering, people skill and character building. Neuroscience and Physics has no clear direct connection with my profession. It is exactly the completely out of band domain knowledge that indulged me to taste the pure joy of satisfying the fundamental curiosity I had long forgotten since a kid. I intend on making reading extracurricular books a hobby of mine to broaden my horizon as a person.

Now to my thoughts on the book. While the book was not hard to read, the ability to understand data/statistical plots helped me a long way. The book surrounds around the theme "time" and breaks into three parts of discussion. The first and second part focuses on the biology/psychology and physics view of time. The third part is where the most fun is at for me. It related free will, consciousness and ultimately one's responsibility to how our time perceives time.

I really enjoyed the book because I was concerned the book might be a textbook that solely focuses on science theories. The book turned out to be a relatively light read where the author raised a lot of awareness on how our brain relates to what we took granted from our daily activity. For example, how does one determine where the sound comes from? Or why the visual and audio effect of one event seems synchronized when light travels way faster than the speed of sound? It was a lot of fun to realize that what seems simple and intuitive to us actually has our brain constantly working in the background. Just like technology where user is served with convenience on a platter when layers and layers of engineering effort was put in place. What we took for granted in our daily live, our brain had to do complicated processing to provide us this simple easy illusion.

While I did not agree with some of the philosophical argument towards the end of the book, a lot of theories were well presented in the right level of depth for a non-philosophical background person like me. One of the great insight that I gained from reading this book is that the mental time travel in our brain allows us to travel into the future via our brain. Such ability is unique to human being but it is both a blessing and a curse. It is a blessing because it allows us to plan ahead to mitigate our risk to increase our chance of survival. It is also a curse because it can make us overly worrisome about what is to come and forget to live in the moment. Being a person who plans and worries a lot about the future, this is a great comfort for me to learn that my anxiety and desire to map out the future ties with the very fundamental architecture of my brain.

I really enjoyed the book, I would recommend you to give it a try if you have always been fascinated about psychology, biology and physics. As an engineer, we spend most of our time designing new technology to solve challenges in our life. It seems crazy to not know more about the very physical being that carries ourselves around. This book left me with more thirst to learn more about the human body and mind.

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## George Siehl says

A challenging read that gives one much (too much?) to think about. The fields of biology, physics, and philosophy offer insights into how we relate to Time. Mystery pervades the text, with the author declining to offer a definition of Time, while proceeding to explain how fundamental it is to the functioning of the human brain, a mechanism of multiple clocks, as he describes it.

The first half of the book, "Brain Time," deals extensively with neuroscience and the functioning of the mass of neurons, synapses, dendrites, and axons, some 100 billion of them, comprising the brain. It is these multiple messaging systems which contain the clocks whose purposes Buonomano describes. The section also presents two concepts of Time itself, presentism, in which only the present is "real," and "eternalism," which accepts the reality of the past, present, and future. Of interest in the section is the matter of how individuals perceive time, for instance in periods of crisis or trauma. One frequently described perception is that of the slowing down of events. This is generally thought to be a later recollection of events, not the true experience of the moment. The author does allow for exceptions, as in the case of individuals trained to deal with a given kind of stressful situation, as in the case of professional athletes who speak of the perception of slow motion on a given play (although they also speak of the game being faster at each higher tier). The author does not address the sportscaster cliché after many quarterback sacks of "the clock in his head that should be letting him know when he must get rid of the ball."

Part two examines "The Physical and Mental Nature of Time." We learn how clocks of seemingly impossible accuracy are made to measure a wide range of time scales, a major difference with the brain's own specialized timing mechanisms. The "flow" of time and "Time's Arrow" are examined, along with the reasons why time does not flow in the view of some specialists. An interesting aspect of discussion is the role of language in dealing with time: frequently the discussion will use spatial terms, as in "the past is behind us," and "the future lies ahead." One explanation offered for this is that the brain uses the circuits developed for navigation to deal with the concept of time.

Cumulatively, Buonomano presents a wide range of ideas, many of which are in conflict with one another; discussion of why all of this matters (to help us prepare for the future); and shows a number of researchers investigating the many aspects he touches upon. He includes many real life applications of what he discusses. Still, in the end, the diversity and differing opinions may overwhelm the reader, who may ask, "How does this all relate to me: what should I do about it?"

This focus on the physiology and psychology of the individual concerning time may help to make some sense of time as it relates to the broader operation of society. There are a number of good books that examine the role of time in the broad functioning of society. A personal favorite is the foundational, "Of Time, Work, and Leisure" by Sebastian de Grazia. The book is an interesting interplay between the increasing regulation of peoples' lives through the increased importance of clock time through history, versus the increasing desire for many parts of society for more leisure time.

Murray Melbin's "Night as Frontier: Colonizing the World After Dark" explores one means of trying to make more time usable by expanding work and leisure activity into the night. He cites a number of trends and their consequences associated with this effort to make the day longer.

In a third socially centered look at time, "Disenchanted Night: The Industrialization of Light in the Nineteenth Century," author Wolfgang Schivelbusch describes the application of technology to provide illumination after darkness through such techniques as street lamps. His description of the lantern smashing

riots indicates some social opposition to this amenity. An interesting historical review.

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### **Nilesh says**

Time is a complex subject without satisfactory answers. These inherent aspects of the topic hurt the book's utility.

Time poses different challenges when viewed from different theoretical angles. It is a subject studied in great detail philosophically (including spiritually) and scientifically for millenia. The book tries to summarise some of these characteristics but does not even scratch the surface. Excellent popular books are written on these sides of time. Anyone who has read such works is likely to find the relativity, entropy-driven, history-centric or spiritual discussions in this book highly perfunctory.

The book title promises discussions from psychological and neurological angles. The author is a specialist here and his expertise provides illuminating insights when the book sticks to this core objective. The author argues that our brain is a clock with some memory in a sense: it stores past information, processes them as needed to help us get more out of the present and the future. The way this clock has evolved, it is imprecise compared to the mechanical clocks humans have designed but functional enough to help us survive.

The author has some great nuggets all through in these discussions. For example, our brain clock differs from the computer clock in the most basic way: computer clocks execute processes in terms of the number of full cycles while the brain clock does operations within one full cycle. Research studies to throw light on the extent of imprecision of our body clock(s - there are many different varieties) make some fascinating readings.

And yet, the subject matter renders most conclusions highly ambivalent and practically of limited use. They come in the way of making the book better than it is.

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### **Richard says**

All us can look at a clock and know what time it is but who among us knows what is time? That is just the first of many issues raised by Dean Buonomano in this fascinating book.

Dr. Buonomano leaves defining what is time, if time exists, or is it something humans invented unanswered because, as of now, no-one seems to know. We know, because of Einstein, that time is relative. We do know time is subjective - that it seems to go faster when we are having fun than when we are bored. We know that we can "time travel" and imagine the future. We know that we can remember and build on the past. We know that our brain distorts our sense of time. But does any of this help us to understand what is time?

I found this book to be fascinating. Buonomano delves into both the mystery of time as well as the conflicts between how physics, psychology, philosophy, and neuroscience perceive and explain time. Does time only exist in the immediate now or does all of time - past, present and future - exist simultaneously?

Even if you skip over explaining what is time, you run into the question of how does our brain perceive time.

The neuroscience part of the book shows that there are many different types of time sensors in the body, located in many different areas - including down to individual cells - and that these time senses can be fooled in a manner similar to optical illusions.

One of the interesting ideas that Dr. Buonomano introduces is that our sense of time grew onto our already developed sense of distance. Knowing how far away a hungry lion is was more important than knowing what time of day we observed him. This might explain why so many of our words describing time are distance related such as far in the past or nearly time.

Some of the science is pretty "deep". I have never fully understood the whole neuron - synapse process. Despite that, Buonomano presents the information and concepts clearly and, for the most part, in an easy to understand way. Of course, if you really want to dig into the science further, the notes and bibliography sections make up about 30% of the book.

After reading this book, you may find that you never look at time quite the same way again.

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### **Mike Putnam says**

Fascinating topic, but a dry read in some spots. It also seemed that the concluding chapter ended somewhat abruptly, with interesting discussions such as the concept of 'free will' receiving incredibly short shrift. This book should be read in tandem with Burdick's 'Why Time Flies.'

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### **C.T. Phipps says**

One of the more comforting things I find about the universe is that scientifically speaking, death doesn't exist. This is something which we don't discuss much because science and religion are sometimes at war with one another (with the exception of some versions of Buddhism and Hinduism).

Einstein pointed out to the widow of a close friend that while it appeared she lost her husband, he existed alive and well in the past and would eternally. He was no more dead than simply being in a different spot in physics due to the model of universal block time. I.e. the universe is a big block of cement we're just a line moving through. My father, grandfather, and brother are all alive in the "next room" so to speak and when I'm dead--my relatives will be alive themselves.

For those more familiar with comic books, Alan Moore created the character of Doctor Manhattan who experienced time simultaneously. Which is, according to the way physics exists, is probably how things SHOULD be experienced and might be how any aliens we encounter will experience time. A more religious answer is the fact God would experience it this way or a theoretical panpsychic entity consisting of the universe (which is not scientifically impossible). All this sounds like rubbish but so did the concept of a meteorite before people found out rocks really were in the sky.

Dean Buonomano talks about time and the concept of evolution with a very interesting idea: that basically "time" as we perceive it is an evolutionary advantage. Physically, time is just moving from one position to another but the concept of beginnings, middles, and ends are the result of our body being designed to make it easier to predict consequences so we can avoid them. In short, as the Hindu would say, time is an illusion.

There's some definite problems with Dean's portrayal of the subject with the idea of our minds as "mental time machines" running into some issues with quantum physics. While block time is probably 99% true, the 1% is niggling and the nature of quantum physics may mean that its actual complete nonsense (and we're not a line moving through a block of cement but a drop of water moving through an infinite ocean of equally identical drops of water--which might make the oddity of the way we evolved even more so).

Part of the big issue of this book is the untestability of the hypothesis as while it certainly sounds right, the simple fact is we don't understand quantum physics OR consciousness with any real degree of certainty (so much so the only person who has put forth any real solution to it is Roger Penrose and he's something of the Alan Moore of physics in terms of being both amazing as well as a little crazy). So this comes off as a bit more like a philosophical treatise than a hard look at how our perception of reality functions.

It's a good theory, though.

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## **Magdalena Otap says**

This was a very extensive book on one of my favourite topics: Time. It covered time from different perspectives.

Physical time:

- The "objective" time that we measure with clocks
- Time as the fabric of the universe (part of 4D spacetime) as defined in Einsteins relativity
- Time as a parameter that governs the evolution of a quantum system and the conflict of the role of time in quantum mechanics and the relativity theory

Biological time

- Our circadian clock and sense of time related to day/night
- Why and how did we develop our sense of time?

Neurological time

- How the brain keeps time - different areas of the brains and their function
- Prospective and retrospective timing and the subjective feeling of time, depending on weather you try to tell time that has passed or try to count time prospectively
- "Mental time travel" and how human brain differs from animal brains in relation to keeping time and "mental time travel" to the past and the future
- How our consciousness is related to time and only shows us "summaries of time short periods"

Also very interesting discussion of presentism vs. eternalism. In the presentism the "now" is all there is. Past is merely something in our memory and future hasn't happened yet. This is a common view in neuroscience. In the eternalism the universe is a "block universe" where time is merely a 4th dimension and "now" is just a point in the 4D block. "Now" is not a special point. This view is commonly used in physics. Is the flow of time then merely an illusion?

At times the book can be hard to get through, but it is definitely worth a read for anyone curious about time as a subject.

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## **Eryk Banatt says**

An average book, which ended up being a bit of a chore to get through.

This book seems to be trying pretty earnestly to be a comprehensive look at time, but ends up being what feels like a large collection of loosely tied together anecdotes about time. Each section has almost enough cited info to form an intro university course's syllabus, but none of them quite reach it, and the book feels shallow as a result.

Buonomano explores a lot of different fields. Philosophy, eternalism vs presentism, free will, timeless physics, relativity, developmental psychology, evolutionary psychology, time perception, the list goes on and on and on, all topics of which full books could themselves be written about. Most of the interesting and useful information is in the first half of the book, with the second half mostly being about the nature of time in general rather than time as it pertains to humans. Where this book shines is that the citations don't suffer along with the breadth - everything is well researched, and any layperson question you might have about time probably has a citation in this book with an answer.

Overall a pretty normal nonfiction book that broadly speaks about a big topic.

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## **Tony says**

It contains a good amount of recent thought about the workings of the mind and the timespans that we require to build a narrative of our experiences and react accordingly. There is a lot of discussion about the history of time as a concept that I have read many times before, which I read with pleasure, despite knowing most of it, because time is a subject I have been passionately interested in since the 90s.

He briefly mentions and dismisses George Ellis' idea that time exists in the past exactly as described in standard theory, but that the present moment is a special state that becomes time and space, which has been the prime reason for my fascination with time. Even his brief mention of Prof. Ellis' theory, which matches exactly my long-standing intuition, caused me unspeakable joy. Not many people will ever feel the incredible relief of finding their private thoughts transformed, in a moment, from a "cock-assed" idea into a respectable theory by an eminent professor of mathematics, but I can attest that the feeling is incredible. He ends by touching on the obvious fact that when we project plans into the future we are doing something only a few exceptionally smart animals can do very crudely, hence the title. In sum, a readable, fairly comprehensive look at some recent experiments in neuroscience and the nature of time as seen in current physics.

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## **Anders Rasmussen says**

I feel obliged to admit that, like the author, I am a scientist working on the neuroscience of timing. There are not many non-fiction books about time, behavior and neuroscience and therefore I simply had to read this book. And I am glad I did.

The book begins with a summary of the psychology, philosophy, pharmacology and physiology of time. The author has an excellent grasp of the issues at stake and the importance of doing research on these topics. How do humans measure short and long time intervals? What is the shortest time interval that we can detect?

How does our body know when to go to bed and get up again, and how accurate is this circadian clock? How do drugs affect our time perception, and what does that tell us about the brain? How can neurons or neural networks detect measure time? I don't agree with everything he says about the neuroscience of timing. However, it was a joy to read these chapters and, on their own, these six chapters justified the time and money spent on this book. During my own studies, I have read tons of studies on timing employing a broad spectrum of different techniques. This book helped me connect the dots and get a bird eyes view which is something that can get lost in science.

The book sidetracked a bit in chapter seven where Buonomano takes on the physics of time and the philosophical implications. Does time even exist, or is it (like many other things), a persuasive illusion that the brain construes to give us an advantage in evolution? Is presentism (only the 'now' exists) or eternalism (time is another dimension and 'now' is to time what 'here' is to space) the correct model of the universe? What does our subjective sense of time tell us about time itself? These more philosophically oriented questions are taken on, at depth, and Buonomano even gets into the 'shooting particles in moving trains' thought experiments to explain the implications of Einstein's theory of relativity. I, perhaps naively, did not expect to encounter so much of Einstein in this book, but in the author's defense, he does an excellent job of explaining the implications of relativity, and he even manages to link it back to the psychology and neuroscience of timing.

In the last chapter, the author returns to the core issues. He discusses whether animals plan for the future (they clearly do) and whether they reflect on the future in the same way that we do (debatable). We also get to meet the Pirahã tribe who, according to an anthropologist/missionary who lived with them, lives in the here and now. They were, for instance, quite unimpressed with Christianity when they realized that their visitor had never actually met Jesus. In the last chapter, the author also takes on free will. If time is just another dimension that we can, at least in theory, travel across, then that should logically mean that everything that is going to happen has already happened which presumably means there is no free will. Free will, the author suggests may only be the feeling associated with making decisions - just like we feel pain when we get painful stimulation.

All in all, if you are interested in time and its relation to human behavior - then this book is the book is for you.

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### **Bernd Meyer says**

Excellent where the author sticks to his guns: neuroscience and psychology. But the excursions into physics and philosophy are shallow at times and not always correct. Ultimately, the book doesn't deliver on its goal to create a unified view of the perception of time. It could have been a much better book if the author focussed on neuroscience. Despite this worthwhile reading.

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### **Dan Graser says**

This is a fantastic introduction to the relationship of our modern concepts of time to the very fine detail we have as to the workings of the brain. Dean Buonomano very clearly spells out what he means by calling the brain a time machine:

- 1) The brain is a machine that remembers the past in order to predict the future.
- 2) The brain is a machine that tells time.
- 3) The brain is a machine that creates the sense of time.
- 4) The brain allows us to mentally travel back and forth in time.

There are no woo-woo, non-scientific notions of the supernatural, consciousness, time-travel; everything presented here is done so in light of the latest in neuroscience and presented in very clear language. Of particular interest is the concluding chapter which brings in the concept of free will but for whatever reason the author seems to abruptly stop the work there when it appeared there likely could have been another 50 or so pages of material. A wonderful introduction free of the BS that frequently pervades discussion of these topics.

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### **Cristina says**

Great overview of how the fields of physics and neuroscience approach the study of time: how they overlap and where they butt heads. Historical context, thought experiments, and countless research studies form the framework for how our concept of time has evolved across fields of study. Circadian and biological rhythms inform our mental alarm clocks, but we also employ various levels of more precise neuro-timers to properly parse speech, music and memories. Sundials, crystal quartz watches and atomic clocks capture the external, more objective passage of time, though Einstein's theories of relativity counter any hope of leaning on time as an unqualified absolute.

One dichotomy I found super interesting is the battle of presentism vs eternalism. The former holds that the present, the NOW, is the only moment grounded in reality, while the past and future are inaccessible and only exist in our memories or mental projections, respectively. This is the theory supported by our conscious experience - we feel that each passing moment, each NOW, is somehow qualitatively different than any moment in time not currently being experienced. Eternalism on the other hand, posits that time is the fourth dimension and reality can be presented as a 4D variation of a cube --like a block of cheese where the present moment is merely a slice. This is the view supported by modern physics, because time is relative to the observer and there is no evidence to suggest (beyond our intuition) that the present moment is any more real than any other moment in time. The world of scifi rejoices.

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### **Aditya Singh says**

Hard to put down! Brilliantly written, addressed a complex ...in fact extremely complex ....topic in a manner that you flow with it till the end....and beyond!

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### **Juemmin says**

The feeling of time flow, or thinking of past or anticipating of future, maybe is the consequence of human's biological evolution. In theoretical physics, as time combining with space, it gives arise to some new understanding of physical world. However, inside our mental world, the time remains in conjectural and indescribable in a strict scientific sense. Perhaps, it is our mind, which is incapable of understanding what is time, at least in nowadays, stops us from breaking through the barrier of physical time.

To my temperament, it is an agreeable of way to spend time reading this book. Besides those fun facts in physics and neuroscience, as for intellectual gains from the contents of this book, people might find it varied. However, I am still remain skeptical on our capability to conquer the theoretical definition of time, and thus failing to identify a path to a better understand of our physical world (This may not be the attention of this book). However, in practice, we can still make our world a better place when we exam our decision involving time, and thus, continue walking on the path of evolution as time prescribes.

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