



# (for once) **On Time**

Patrick Pilarski

Amii Meetup  
2020 October 15



# Approximating Time

Patrick Pilarski

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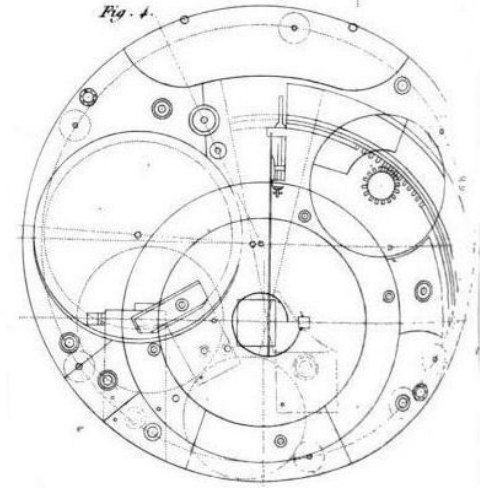
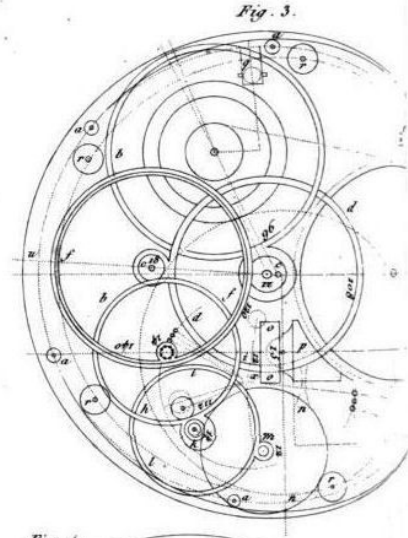
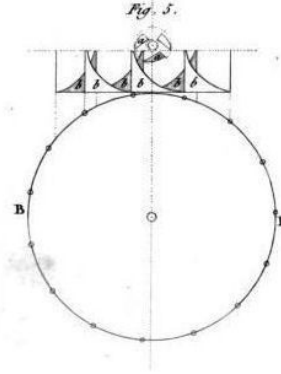
# Approximating Memory?

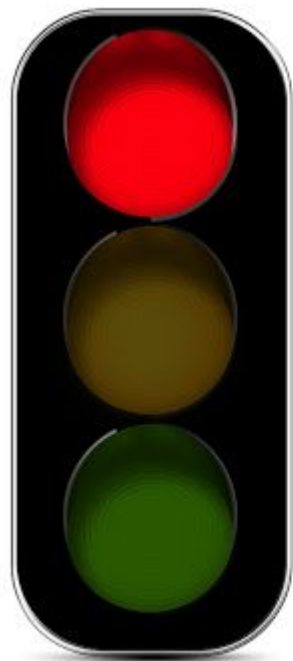
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# Goal for today:

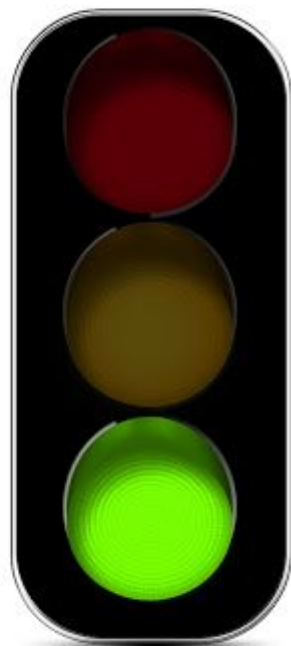
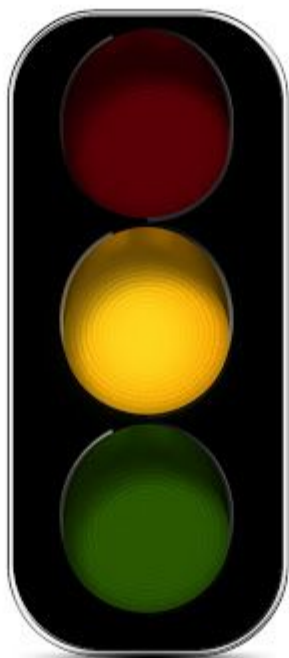
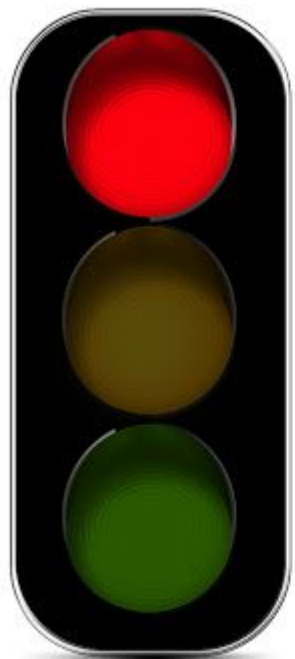
get you thinking about **time** and how it is involved in the operation of learning machines.



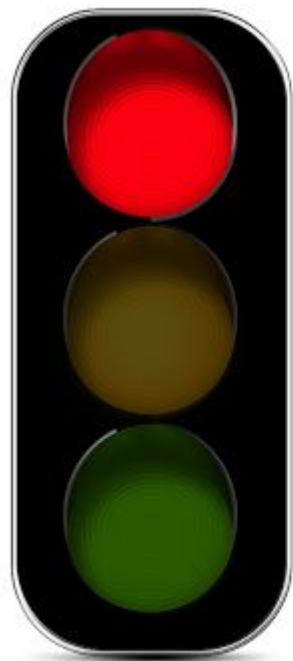


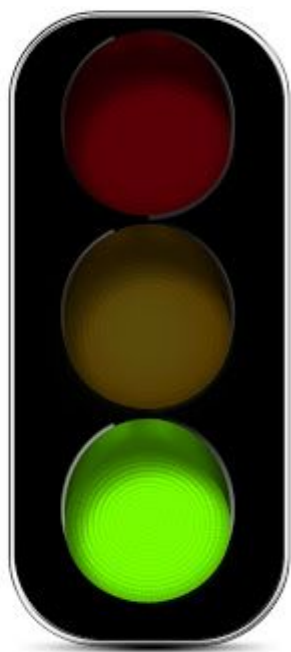




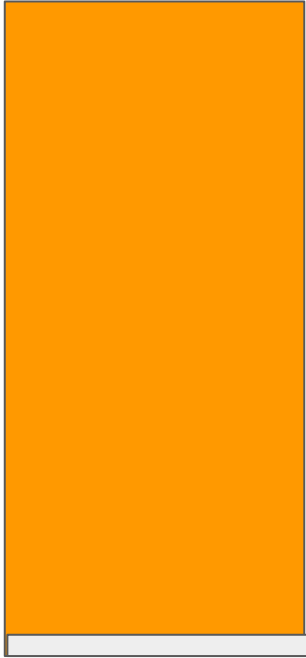




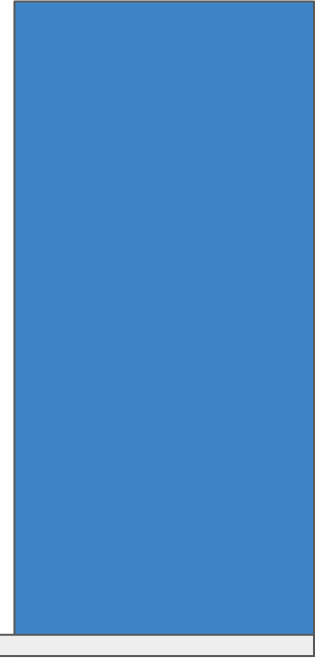




**CONDITIONED  
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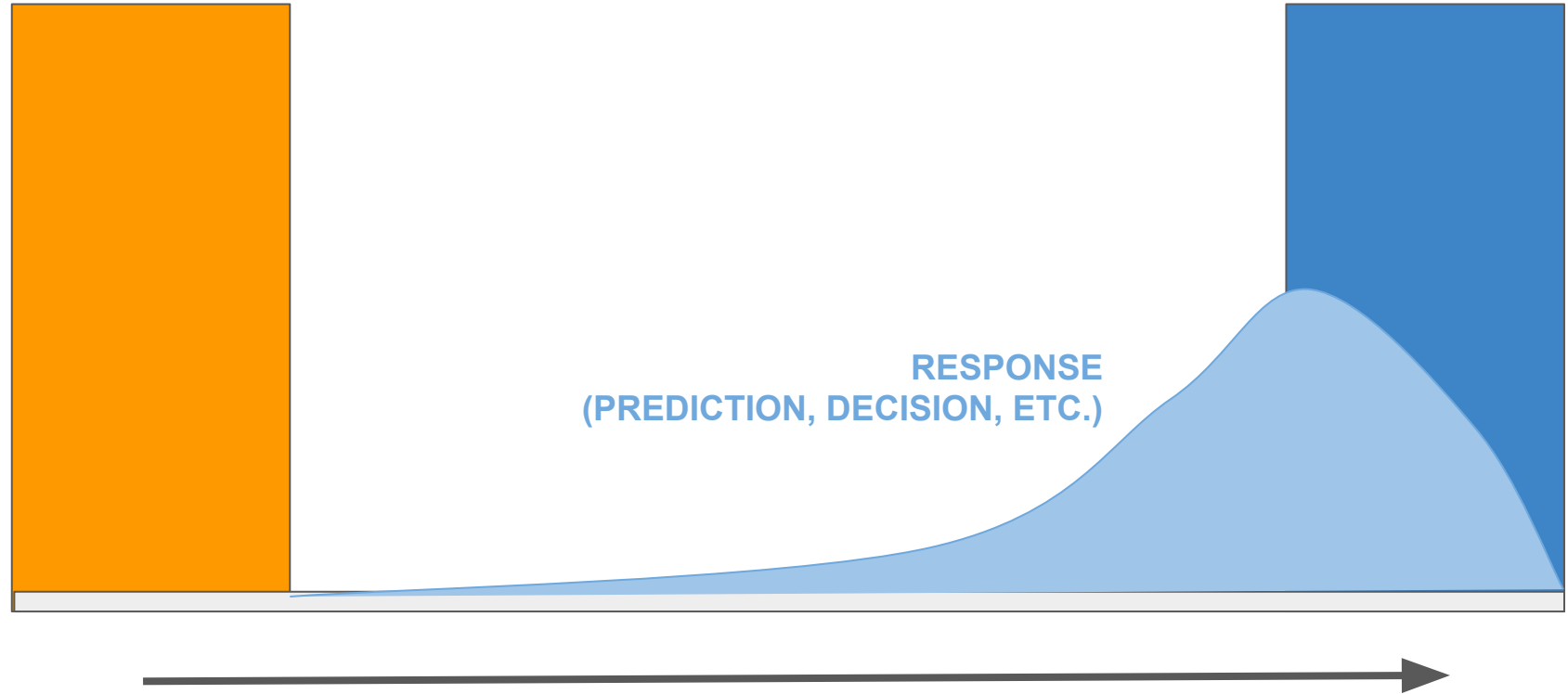


**UNCONDITIONED  
STIMULUS**



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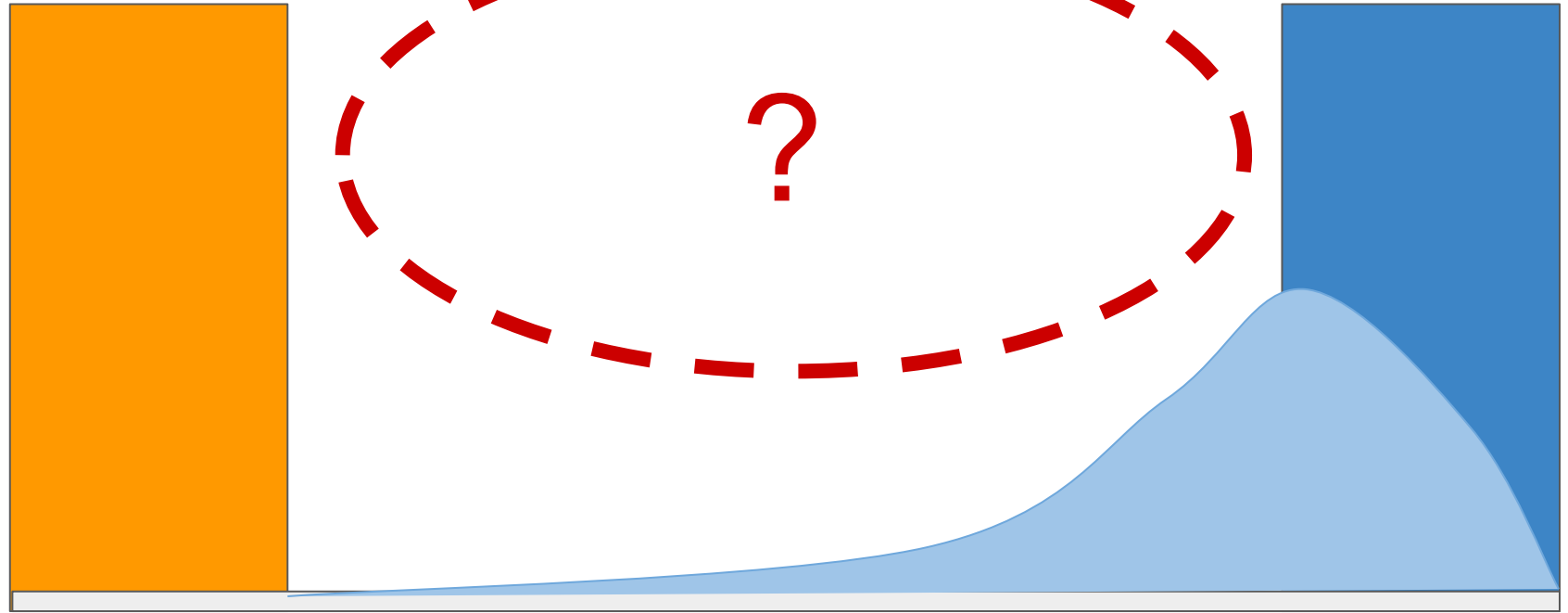
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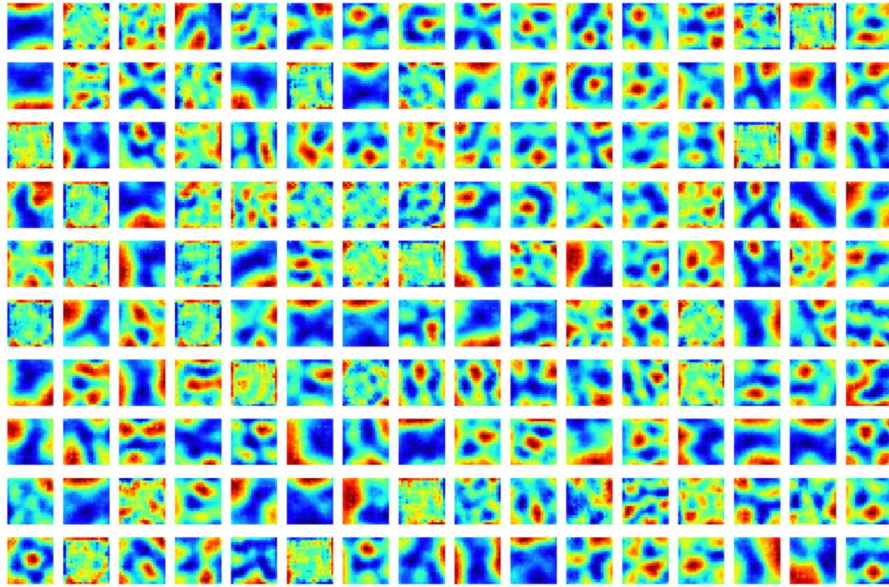
Of note: ***Trace conditioning***, c.f., Pavlov (1927), London: Oxford University Press.

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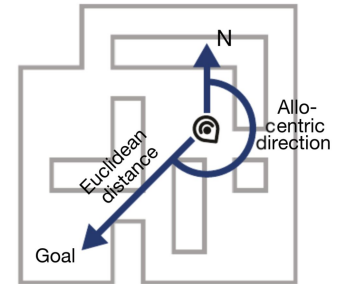


Of note: ***Trace conditioning***, c.f., Pavlov (1927), London: Oxford University Press.



# Cognitive Maps

Tolman (1948)



## ***Place cells and grid cells in animals and machines:***

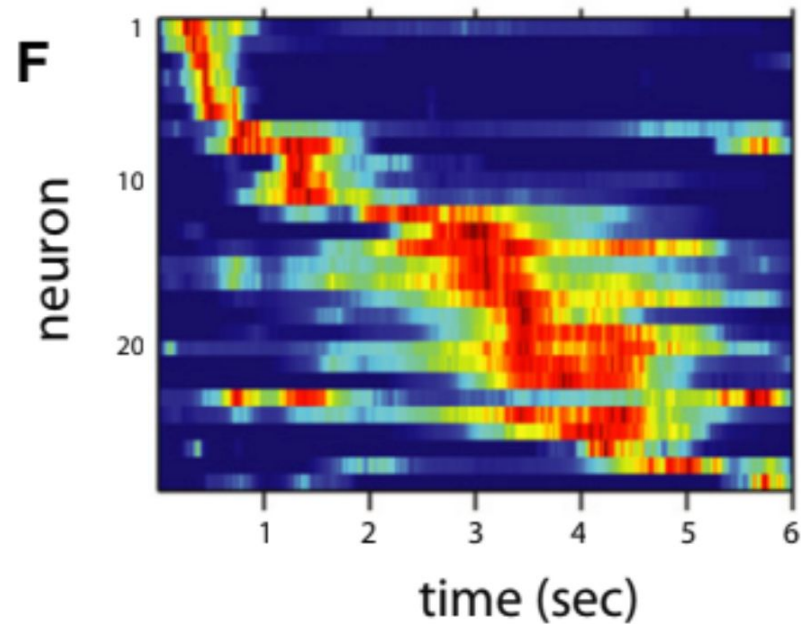
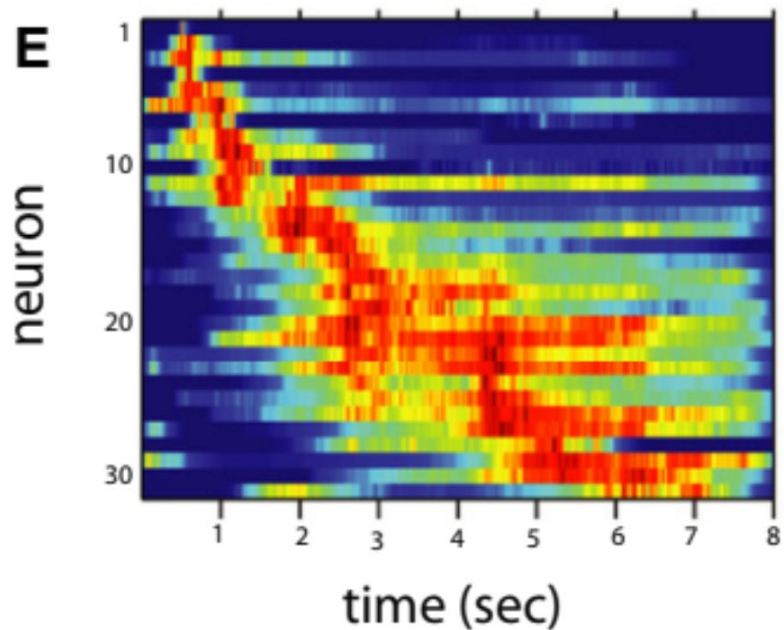
O'Keefe et al. (1971). *Brain Research*. **34** (1): 171–175;

Haftting et al. (2005). *Nature* **436** (7052): 801–806;

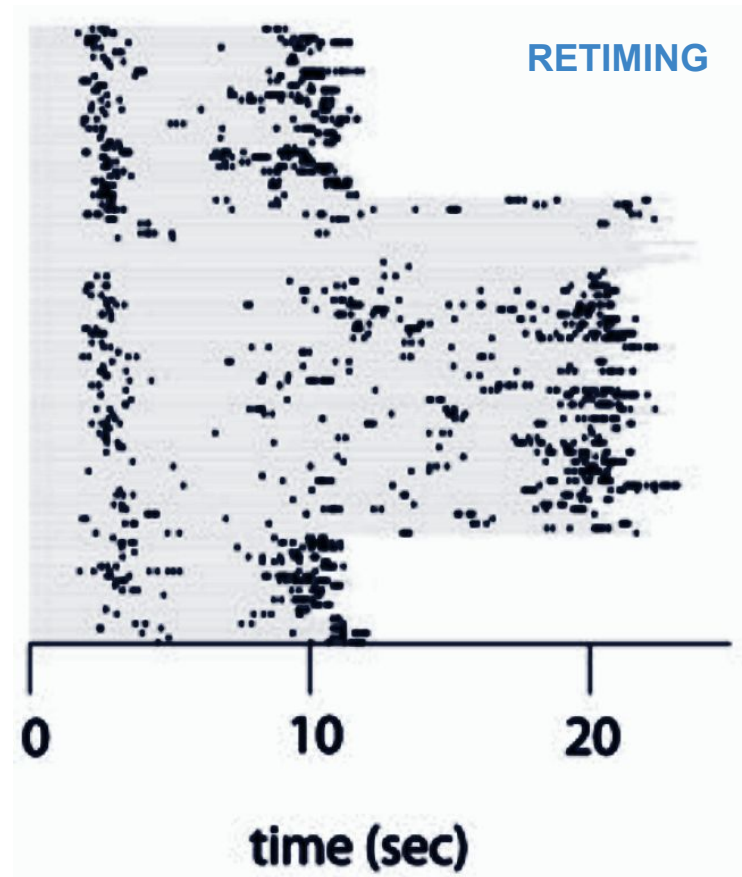
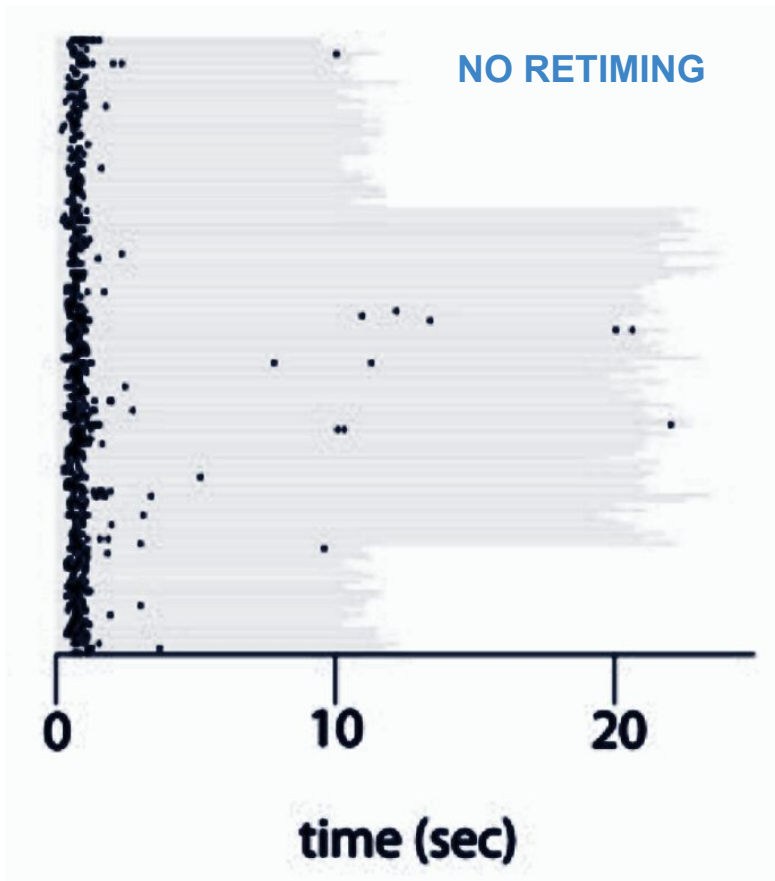
Cueva & Wei (2018). *ICLR*;

Banino et al. (2018). *Nature* **557**, 429–433.

temporal modulation, independent of location and behavior

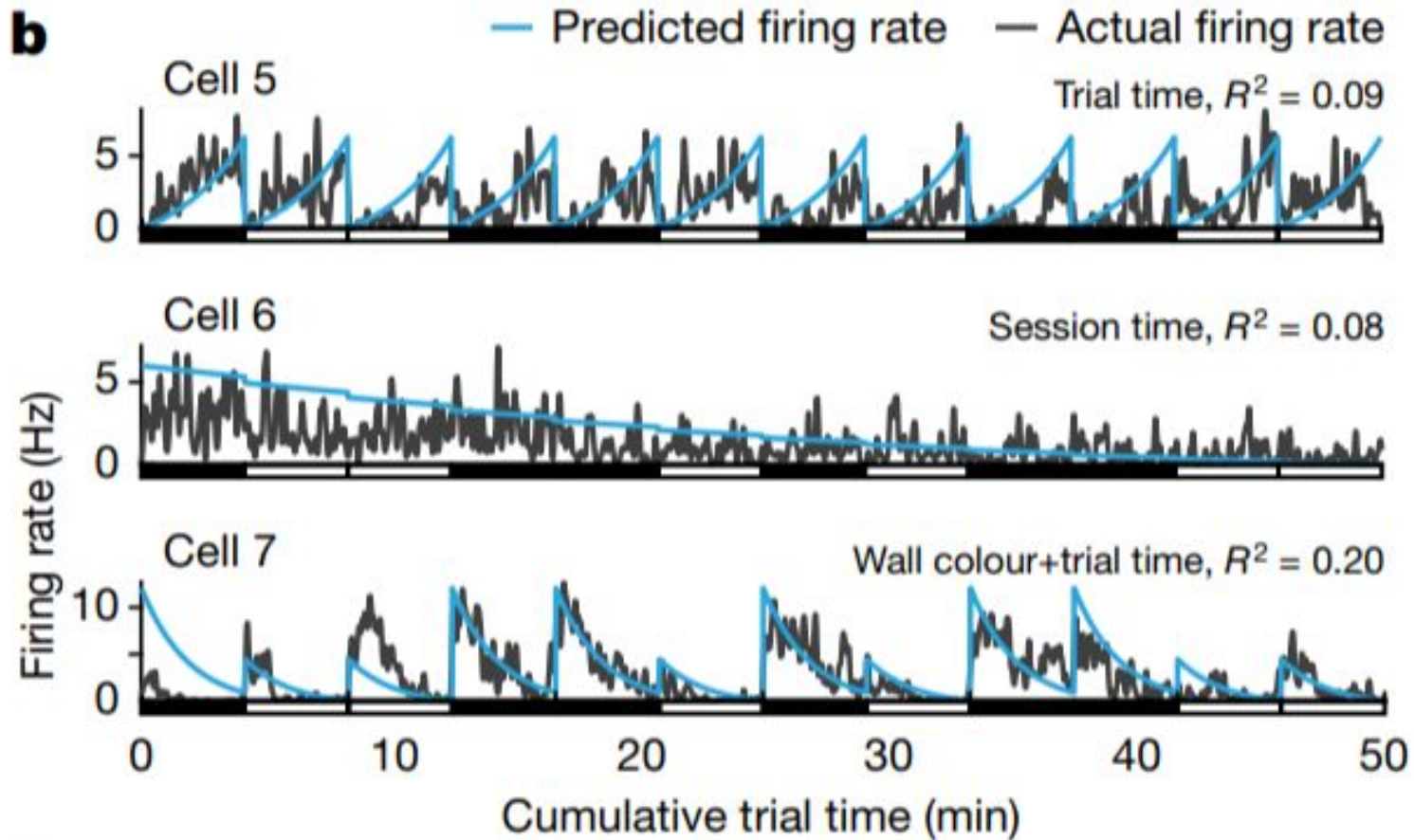


***Time cells in the hippocampus***, as studied by MacDonald et al. (2011), *Neuron* **71**, 737–749.

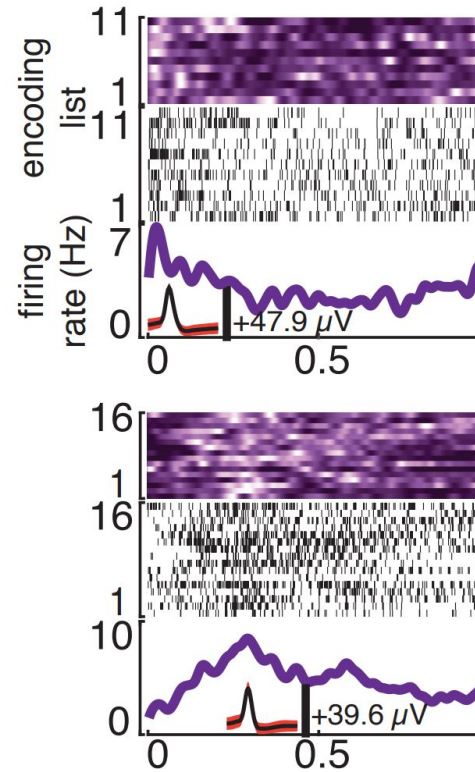
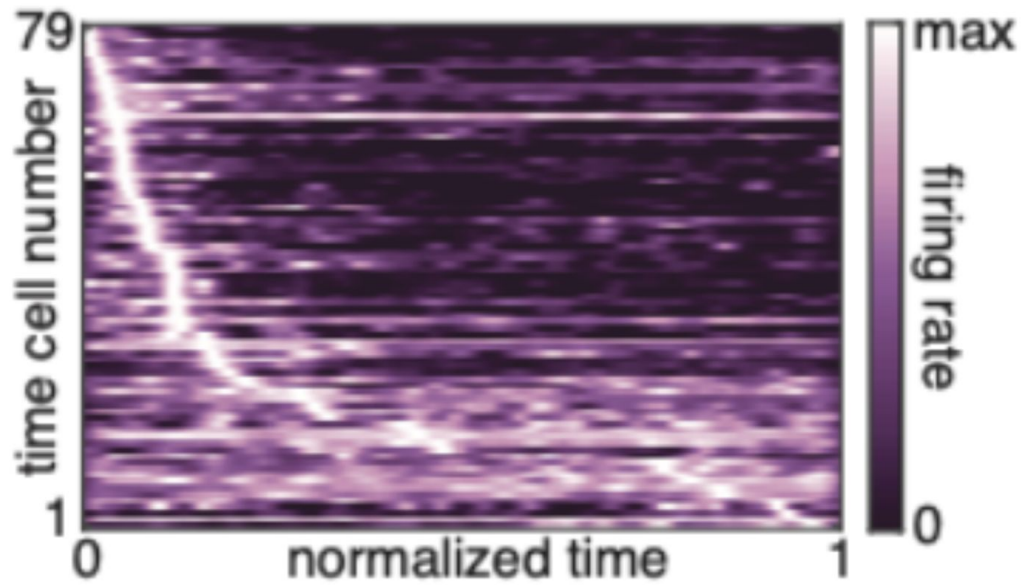


MacDonald et al. (2011), *Neuron* **71**, 737–749.

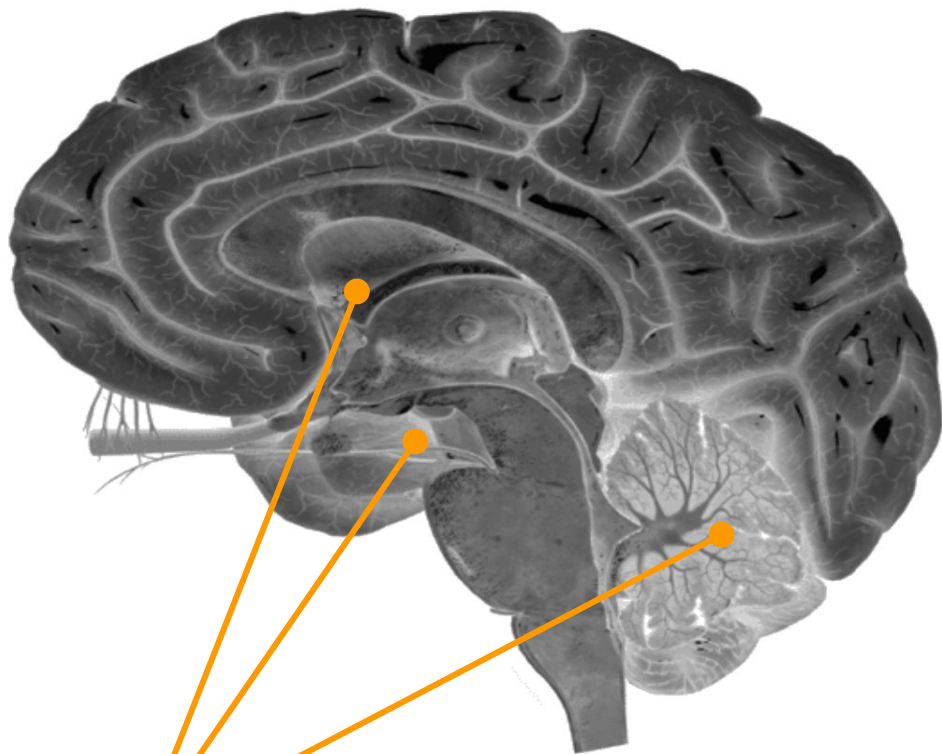




**Ramping cells** in the lateral entorhinal cortex, Tsao et al. (2018), *Nature* **561**, 57-62.



**Time cells in humans**, Umbach et al. (2020), *preprint, bioRxiv*.



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**Cerebellar, hippocampal, and striatal time cells**, Lusk et al. (2016), *Curr. Op. Behav. Sci.* **8**, 186–192.

# The animal brain uses time to:

- Remember the past to **predict the future**;
- Recognize and generate **temporal patterns**;
- Create the subjective **perception of time** (be able to make the flow of time visible and representable)
- **Project** back/forth in time (remember and simulate)

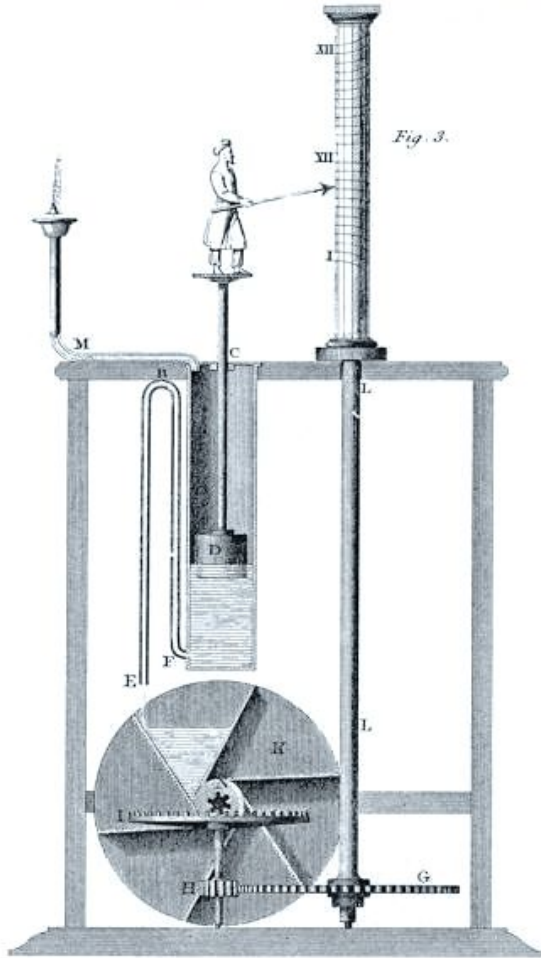
Adapted from *Your Brain is a Time Machine*, Buonomano (2017), N.Y. : W.W. Norton & Company.

# My view:

- time is a thing to **represent** and turn into state;
- time is a thing to **predict**;
- timing is a thing to **control**;
- time is a thing to use in **planning** and meta-learning.

# Considerations:

- Prospective and retrospective time;
- Objective vs subjective time;
- Multiple scales: milliseconds, seconds, minutes, hours, days, years, eons;
- Retiming and rescaling of temporal events;
- Entrainment & aligning to temporal patterns.

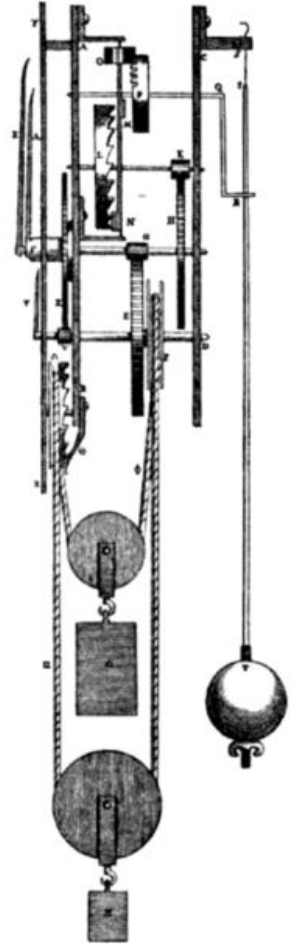


## Desirable agent abilities:

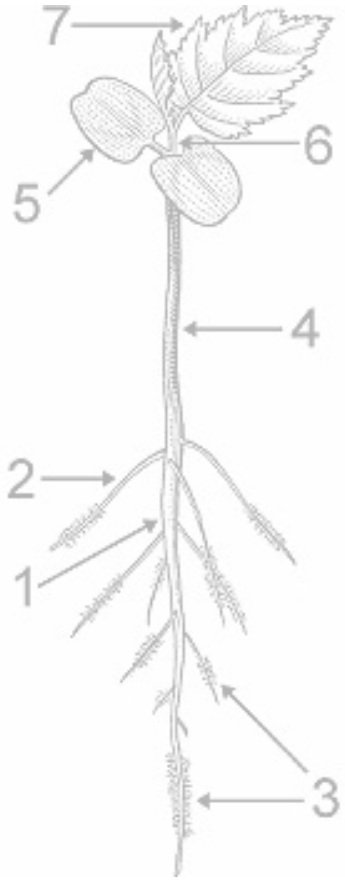
- **Represent** time since an event(s);
- **Estimate** time until a future event(s);
- **Scale** & **adapt** to event intervals;
- **Align** to rhythmic events;
- **Use** and change the environment to implement objective time.

# Some themes of my own ongoing work:

- Understand **prospective and retrospective timing** in machine agents;
- Understand how agents use (and build) **representations of how time has flowed and how it will flow** during life-long decision making.





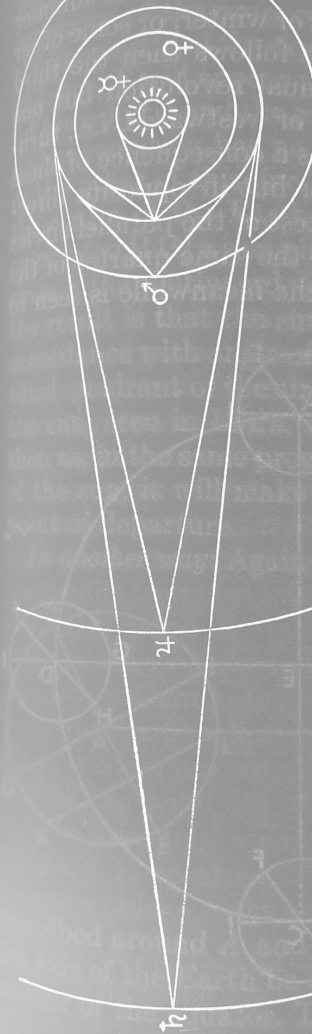


## Some suggestions for the present:

- **Take your time.** Focus on personal understanding at your own pace.
- **Protect time** for yourself. You are more important than your perceived productivity.
- **Make time** to do things that help your physical and mental well-being.

# Time's up

(and questions)



...the greater  
the moved and the unmoved.  
is the godlike work of the Bes

11. A DEMONSTRATION OF THE  
MOVEMENT OF THE PLANETS

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mony on the part of the plan  
the mobility of the Earth,  
summary of its movement, i

<sup>1</sup>In the three upper planets, the  
apparent progression and retrogr  
tex the centre of the planet and a  
drawn to the orbital circle of the  
planets, however, the vertex of th  
the Earth and the sides are the t  
bital circle of the planet. It is eas  
the relative magnitudes of the o  
progression and retrogradation  
Saturn than in Jupiter, and smalle  
and greater in Venus than in Me

<sup>2</sup>The interchanges of progressio  
proportional to the number of ti  
the outer planets and the inner pl  
Now the Earth overtakes Saturn  
Jupiter more often than Mars, M  
taken by Venus, and overtaken le  
Mercury. Hence the frequency o  
gradation is in that order.

<sup>3</sup>According to the Ptolemaic so  
only from the changes in magni  
what its relative distances from  
and apogee. But according to th  
follows from the relative distance  
and at apogee—which are as 1 to  
iameter of the planet should vary  
assuming that the planet could be  
with the sun.